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14. ABSTRACT
This TOP provides basic information to facilitate planning, conducting, and reporting testing of collective protection (ColPro) active and passive systems in a chamber. Systems include active shelters, passive shelters, and vehicles. This TOP provides a set of tests to assess the air handling, CB protective capability, and operational performance of ColPro systems. Pressurization, airflow, purge, leakage, static challenge, dynamic wind-driven challenge, and entry-exit tests are included in this TOP. The contaminant may be a toxic industrial chemical vapor, simulant vapor, or aerosol of agent-like organism.

15. SUBJECT TERMS
Collective protection; ColPro; shelter; tent; vehicle; airlock; protective entrance; PE; toxic free area; TFA; vapor; aerosol; simulant; military exposure guideline; MEG; chemical biological; CB; protection; pressurization; purge; static; dynamic; entry-exit

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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure 08-2-199   4 September 2019
DTIC AD No.

COLLECTIVE PROTECTION (COLPRO) SYSTEM CHAMBER TESTS

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1. <u>SCOPE</u>.

1.1   <u>Background</u>.

   a. Collective Protection (ColPro) systems are designed to provide protection of enclosed personnel, supplies, and equipment from threats including Chemical Warfare Agents (CWAs), Toxic Industrial Chemicals (TICs), Biological Warfare Agents (BWAs), and radiological contaminants.

   b. ColPro systems provide a Toxic-Free Area (TFA) where personnel can function without the need of Individual Protective Equipment (IPE) during threats. Systems may be active or passive. In an active system, the TFA is over pressurized with filtered air to significantly reduce the potential for direct agent intrusion caused by ambient winds. Active systems obtain filtered air from a Gas Particulate Filter Unit (GPFU), a blower equipped with a Chemical, Biological, and Radiological (CBR) filter (a High Efficiency Particulate Air (HEPA) filter to remove particulates, and a carbon filter to remove toxic vapor). A Fan Filter Assembly (FFA) is the type of GPFU used in most expeditionary ColPro systems. In most ColPro systems, the filtered air is introduced to the TFA through the Environmental Control Unit (ECU) that provides heating and cooling for the ColPro system. Passive systems rely solely on carbon cloth/HEPA filtration panels to maintain the TFA without the use of pressurizing airflow.

   c. Entry/exit to and from the TFA under threat conditions requires the use of an airlock, otherwise known as a Protective Entrance (PE). Passive systems do not have airlocks; their use is mainly as emergency protection devices when imminent threats are perceived and after initial entries are performed, the system is sealed up tightly and no further entries are allowed. The PE is sometimes part of the Contamination Control Area (CCA), but in most operational scenarios, the CCA is the area outside of the PE that is used to doff IPE and decontaminate gloves and mask before entry of the PE. The airlock functions as a staging area that permits toxic vapors from contaminated items to be purged before entering the TFA, thus allowing personnel to move from a contaminated area into the TFA with minimal contamination carryover. A breach can occur if a ColPro system malfunctions or if operational procedures are not strictly observed. ColPro systems can significantly reduce, but not eliminate, the risk of threat intrusion.

   d. Airlocks are also a critical part of the ColPro system because they help maintain overpressure in the TFA and ensure that the TFA pressure never drops to ambient levels. Overpressure in the TFA with filtered air must be maintained at levels high enough to exceed the impact pressure created by winds.

   e. Examples of the different types of ColPro systems are found in Figures 1 through 3.

Figure 1. An active ColPro shelter with airlock and GPFU.

Figure 2. A passive ColPro shelter.

Figure 3. Stryker Nuclear, Biological, and Chemical Reconnaissance Vehicle configuration (a vehicle with ColPro capability).

1.2 Purpose.

a. This Test Operations Procedure (TOP) presents standardized procedures for testing ColPro systems within a test chamber. The chamber may be enclosed using fans to maintain a homogeneous challenge or a tunnel open at one end with air passing through it. In the event that requirements from the Capability Development Document or Capability Production Document differ from those covered by this TOP, the Joint Capabilities Integration and Development System validated requirements in those documents will dictate testing.

b. In this TOP, tents and other similar stationary ColPro systems will be referred to as ColPro shelters. Vehicles and other similar mobile ColPro systems will be referred to as ColPro mobile platforms. Any ColPro system will be referred to as the System Under Test (SUT). The SUT may be composed of fabric or solid materials. Figures 1 through 3 show an active ColPro shelter, a passive shelter, and a vehicle with a ColPro system. The procedures herein may be augmented for use with vessels, aircraft, or buildings if applicable safety protocols are followed, and the procedures are verified and validated before use.

c. This TOP describes validated testing procedures currently in use for the planning and conduct of protective performance tests of ColPro systems and the recommended parameters for each procedure.

d. This TOP provides a complete set of tests to assess the performance and protective capability of ColPro SUTs. The tests are divided into three basic categories: physical tests to determine air handling characteristics of the system, protective assessment tests to measure how well the system protects the user, and system tests that determine operational performance boundaries.

e. The physical tests included in this TOP are Pressurization, Purge, and Leakage airflow tests. Protective assessment tests include the static and dynamic Wind-Driven Challenge Tests (WDCT). The operational tests included in this TOP are the entry/exit tests.

(1) Pressurization tests are conducted to ensure that an active ColPro system can maintain the operational pressure levels specified by the operational requirements or manufacturer's specifications of the SUT. This test is also used to determine supplemental, non-critical data related to pressurization of ColPro SUTs, including the time required to bring a ColPro SUT up to operational conditions.

(2) Purge testing determines the rate at which the PE (airlock) of a ColPro SUT removes contamination brought in during entry from contaminated environments. In a ColPro vehicle, there is no airlock, but purge testing may still be performed. The purge rate is the basis for determining the airlock dwell time used during entry/exit processing. Purge testing can also be conducted on the actual TFA to determine how well the system purges contamination and to provide safety information to determine the initial start-up time, i.e., how long occupants must wear masks inside the TFA after a ColPro SUT is first started.

(3) Airflow leakage tests are used to validate the amount of airflow required for pressurization and purge during operation of a ColPro SUT. These tests allow identification and quantification of areas of leakage from ColPro SUTs that can be sealed to reduce the airflow requirements of the SUT. Leakage testing is not always required for a ColPro SUT, as long as the GPFU has sufficient airflow to pressurize the system and purge the airlock at an adequate rate.

(4) Static challenge tests are conducted to assess whether a ColPro SUT provides adequate protection when operated in contaminated environments. Static challenge testing is conducted by exposing a ColPro system to a high concentration of a contaminant while the system is operated in various configurations and environmental conditions. The Static Vapor Challenge Tests (SVCT) and Static Particulate Challenge Tests (SPCT) are used to determine if a ColPro SUT prevents infiltration of airborne agents into the TFA.

(5) WDCTs are used to assess whether a ColPro SUT's internal pressure is adequate, and determines whether the SUT can prevent infiltration of contaminants when operated in windy environments. Dynamic challenge testing is conducted by exposing the ColPro systems to vapor or aerosol contaminants at specified wind speeds, to determine the minimum pressure required to prevent infiltration at various challenge concentrations, challenge types, environmental conditions, orientations, operating configurations, and wind speeds.

(6) Entry/exit tests are performed to determine whether the occupation and entry/exit rate of a ColPro SUT can be maintained without jeopardizing the safety of the ColPro SUT operators/occupants. Vapor Entry/Exit Tests (VEET) using simulants has historically been the predominant type of entry/exit testing performed. These procedures are used to assess the combined efficacy of the Concept Of Operations (CONOPS) developed for SUT egress and ingress and the system's ability to protect personnel during entering, exiting, and resupplying activities. The CONOPS and the system efficacy are interrelated. Entry/exit is the movement of people, supplies, and equipment between a contaminated environment and the TFA of a ColPro system. Entry/exit testing with aerosols (Particulate Entry/Exit Test [PEET]) has also been performed.

f. ColPro system components should be tested in accordance with (IAW) TOP 08-2-504 Near Real Time Swatch[1]**, TOP 08-2-197 Chemical Protection Testing of Sorbent-Based Air Purification Components[2], and TOP 08-2-201 ColPro Novel Closures Testing[3]. ColPro SUTs may be tested outdoors IAW TOP 08-2-198 ColPro Field Testing[4].

1.3   <u>Limitations</u>.

a. The procedures in this TOP are not sufficient of themselves to assess the ability of ColPro systems to protect the Warfighter. Completion of the procedures in the TOP does not imply acceptance or rejection of the SUT. These procedures are designed to be used as part of an overall assessment program determining material performance, manufacturing, system integration with other pieces of protective equipment, and tactics, techniques, and procedures for the SUT.

b. Some SUTs have subsystems such as weapons or detectors that may affect SUT ColPro performance while operating. This TOP does not cover the function testing of these subsystems.

c. There is no infrastructure large enough to contain every ColPro SUT variant for testing with CWA or other toxic chemicals. These procedures may be augmented or modified to test larger variants with the appropriate Verification and Validation (V&V) of the procedures and infrastructure performed.

d. Field challenge testing may also be performed to assess the performance of ColPro systems that are too large for available test chambers, but will have uncontrolled environmental conditions.

e. These procedures are limited to Chemical and Biological (CB) testing. Radiological test procedures have not been fully developed and validated.

f. The results obtained using this TOP might not be correlated to the full range of battlefield conditions because testing is conducted in a controlled environment.

** Superscript numbers correspond to Appendix E, References.

g. This TOP is limited to currently approved standards and procedures. Developments in practices, equipment, and analysis may necessitate new testing procedures. Additionally, standards of performance shall be adjusted as technologies advance. Test procedures and parameters listed in this TOP will require updating to accommodate new technologies in test items or in test instrumentation. Any modifications or updates should be described in the test-specific Detailed Test Plan (DTP).

h. Toxicological modeling and assessment of mission consequence is not covered in this TOP.

2.   FACILITIES AND INSTRUMENTATION.

2.1   Facilities.

Item	Requirement
Chemical Laboratory.	Required to store and prepare test quantities of chemical contaminants (including simulants) and to conduct all aspects of testing. A facility capable of providing the general analytical support needed for work with contaminants, including sample analysis, instrument standardization, and hazardous waste disposal.
Chamber.	The chamber shall be capable of providing temperature and Relative Humidity (RH) control and containment for agent, simulant, or other contaminant release.
	The chamber shall have mixing fans of size and quantity adequate to ensure that a uniform challenge concentration can be attained with the test item in the chamber.
	The chamber shall have an exhaust filtration system that is capable of maintaining the test chamber at negative pressure (relative to inhabited areas of instrument control areas) so that safety of operating personnel is preserved.
	The size of the chamber relative to the SUT shall be sufficient to provide uniform flow velocity around the SUT and accommodate all subtests (e.g., entry/exit testing). Additional chamber design considerations are found in paragraph A.1 of Appendix A.
Tunnel (wind tunnel).	The tunnel shall be able to control wind speed through the facility and provide a uniform contaminant concentration to the SUT. The tunnel must be of a width and height to provide clearances around the test item to produce side and overhead velocities no greater than 20 percent above the required test velocity.

Biological Laboratory.	Required to store and prepare test quantities of biological contamination simulant materials, to charge disseminating devices, to prepare samplers, and to analyze all biological agent/simulant materials.
Simulant Exposure Area (SEA).	A location where Test Participants (TPs) are contaminated with liquid simulant. The SEA shall be designated in a predetermined spot to minimize contamination of the chamber and SUT by simulant. Spray booths and tentage may be used for liquid simulant application.
Don/doff area.	The location where TPs will don and doff the clothing required for the test.

2.2　Equipment and Instrumentation.

The table below contains a list of measuring devices (equipment and instrumentation) and their parameters for receipt inspection procedures.

Item	Requirement
Challenge generator/dissemination device.	The generator shall be capable of maintaining target contaminant concentrations for the required time period as specified by the DTP. The challenge generator/dissemination device used must produce vapor only and not a combination of liquid and vapor.
Aerosol tracer generation and detection system.	To generate an aerosol tracer for purge testing of airlocks or the TFA and also for SPCT testing with biological or inert aerosols. The detector shall detect aerosol tracer at the required concentrations of 0.001 to 100 µg/L or lower.
Vapor tracer generation and detection system (purge testing).	To generate a tracer for purge testing of airlocks or the TFA. The detector shall detect tracer at the required concentration. Gases in cylinders (Carbon Dioxide [CO_2], and/or Sulfur Hexafluoride [SF_6]) are commonly used for vapor purge testing.
Vapor tracer generation and detection system (filter leak testing).	To generate a tracer for leak testing of the carbon filter systems, e.g., NUCON® F-1000™ HG halide generator (NUCON® International Inc., Columbus, Ohio)[***]. The detector shall detect halide tracer at the required concentration from 1 ppb to 10 ppm.

[***] The use of brand names does not constitute endorsement by the Army or any other agency of the Federal Government, nor does it imply that it is best suited for its intended application.

Data Acquisition System (DAS).	A computer-based DAS that records data. If a DAS is not available or cannot be connected to the data source, data sheets shall be used to record the times and concentration values during testing.
Mixing Fan(s).	Required to achieve a uniform challenge concentration at every location near the SUT. More than one fan may be required.
Recirculation Filter Units (RFU).	To reduce background contaminations in the TFA after entry/exit tests, and also in the chamber to reduce aerosol particle deposition on the floor after SPCT aerosol testing (enhances contamination avoidance effectiveness).

2.3   Instrumentation.

The instrumentation choices are test and test location dependent. The instruments listed below are examples of measuring devices that have been used. Permissible measurement uncertainty values are minimum requirements. Actual instrumentation may have greater precision. Actual values must be reported in the test report.

Parameter	Measuring Device	Permissible Measurement Uncertainty
Vapor challenge concentration.	Gasmet™ (Gasmet™ Technologies Oy, Helsinki, Finland)	±3 percent over the range of 1 to 5000 mg/m³
	MINICAMS (depending on expected challenge level).	±15 percent over the range of 10 to 1000 mg/m³
Vapor breakthrough concentration.	MINICAMS.	±15 percent
Mass disseminated.	Balance.	Accurate to ±1 percent.
Photographs.	Still color camera.	Adequate resolution and photographic size to document typical test procedures, details of contamination techniques and contamination density, and any discrepancies from planned

		procedures necessitated by operational conditions.
Video.	Video camera with time stamp.	Adequate resolution and speed (frames/second) to document typical test procedures, details of contamination techniques, and any discrepancies from planned procedures necessitated by operational conditions.
Tracer gas concentration	Tracer gas analyzer or equivalent Near-Real Time (NRT) detector.	Accurate to ±10 percent. Sensitivity of 0.001 mg/m^3 with a dynamic range of 0.001 to 1 mg/m^3.
Aerosol challenge concentration.	All-Glass Impingers (AGI) and Slit to agar.	Detection sensitivity of 1 colony forming unit per liter of air, and accuracy within ±10 percent.
	Electrochemilumin-escence.	Accuracy ±5 percent. For samples that contain greater than 5000 Genome Equivalent (GE)/mL, the accuracy is within 20 percent of the actual concentration.
	Polymerase Chain Reaction (PCR).	Detection range set between 0.5 to 20 µm, sensitivity of 1 particle per liter of air, and accuracy within ±10 percent.
		PCR data are provided as GE values that can be used to calculate an aerosol concentration.
	Aerodynamic Particle Sizer® (APS™) (TSI® Incorporated, Shoreview, Minnesota) or other similar particle counters.	Adequate particle counting resolution.
	Inert aerosol 47 mm glass fiber filter samplers for Sodium Flourescin (NaFl) aerosol.	Accuracy ±5 percent
	Fluorometers for NaFl aerosol.	Accuracy ±5 percent

Pressure sensor/gauges.	Pressure transducers with digital output preferred, or other pressure measurement device.	Will have a range of 0 to 5 iwg, sensitivity of 0.01 iwg, and accuracy of ±10 percent of the reading.
Leakage test instrumentation.	Blower door or other adjustable flow measurement device.	Flow accuracy of ±3 percent over the minimum range of 20 to 1500 cfm.
Vapor air samplers.	Solid Sorbent Tube (SST) or equivalent devices.	SSTs should have a capture efficiency of at least 99 percent for the selected simulant, flow rate, sample period, temperature, and sorbent material and quantity per tube. Accuracy of ±10 percent.
Flow measurement.	Standard flow meters, Mass Flow Controllers (MFC) desired, or other flow measurement device.	Flow accuracy of ±1 percent over the appropriate range for the sample type: vapor – 2 L/min with a sensitivity of 0.01 L/min; aerosol - 0-30 L/min with a sensitivity of 0.1 L/min.
High flow meters.	Flow meters for high flows in GPFU.	Flow accuracy of ±10 percent over the range of 50-5000 cfm with a sensitivity of 1 cfm.
Temperature.	Temperature sensors, resistance temperature detector, or other weather measurement device.	Range of -18 to 52 °C, sensitivity of 1.0 °C, and accuracy of ±2 °C.
Relative Humidity (RH).	Humidity probes or other weather measuring devices.	Range of 1-100 percent RH, sensitivity of 1 percent, and accuracy of ±3 percent.

2.4   Test Controls.

Unless otherwise specified, the following tolerances will be met for controlled parameters. The tolerance of control cannot be tighter than the accuracy of measurement. Tolerance values will be determined by instrument validation efforts.

Parameter	Tolerance
Temperature, if controlled	±2 °C
RH, if controlled	±5 percent of target value
Challenge concentration	±15 percent

Chamber background concentration	<1 percent of the target challenge concentration
SUT Background concentration	< 0.009 mg/m³ (alternately, 1/3 the Military Exposure Guideline (MEG) value for the agent corresponding to the simulant being used).
Airflow (if controlled)	±10 percent
Differential pressure	±0.1 iwg
SUT Location	±5 m relative to the chamber
Orientation	±5 degrees

3.   REQUIRED TEST CONDITIONS.

3.1   Background.

3.1.1 Familiarization.

    a. Development of test plans requires familiarization with the applicable test planning and requirements documents such as:

        (1) Safety release and approval from the authorizing agency (e.g., U.S. Army Test and Evaluation Command [ATEC]) to begin testing, if required.

        (2) Human use committee approval or exemption and notification, if required.

        (3) Government and manufacturer's publications, including the current Safety Data Sheets (SDSs) for all materials used in the test.

        (4) Program-specific requirements documents: acquisition capability documents, system performance specification, system evaluation plan, safety assessment report, and event design plan.

        (5) Similar and related program documents to avoid unnecessary duplication of effort.

3.1.2 Environmental Compliance.

    a. All local, state, and federal regulations will be followed, appropriate documentation prepared and submitted, and approval will be received before testing begins.

    b. Test personnel and participants must receive and understand environmental documentation before the test begins.

3.2   Detailed Test Plan.

    a. The DTP will be written before test execution and will address objectives of the test center statement of work and include inputs from subject matter experts. Amendments shall be documented and approved by test center management in concurrence with the customer. DTP

format can be test-center specific with customer agreement, but the content will address all elements required for test conduct. The following elements shall be considered.

(1) The DTP shall refer to the data management plan that describes data collection and reduction, analytical procedures, and reporting procedures. With customer concurrence, the data management plan may be included in the DTP.

(2) The DTP shall include safety procedures addressing hazard analysis, operations, and decontamination.

(3) A test readiness review and operational readiness inspection shall be performed before testing begins.

(4) The DTP shall define the required challenge and breakthrough concentration ranges of the contaminants, accounting for the trial conditions and the contaminant's physical and chemical properties, analytical limitations, and safety considerations. The DTP must address the criteria for system evaluation and is defined by the system requirements documentation.

(5) The DTP shall identify suitable challenge systems and referee instrumentation based on the contaminant(s), concentration, and environmental conditions. The DTP shall specify whether the system will be operated under its own power or under shore power.

(6) When a new SUT is developed it is recommended to use computational fluid dynamic modeling to determine the optimal location and placement of the SUT and the instrumentation. If a new chamber is built, then computational fluid dynamic modeling must be used in the chamber validation process.

(7) The TOP procedures may require modification for unique items, materials, or to satisfy specific testing requirements as specified in test program documentation. Procedures will be modified only after full consideration of any possible effects on the reliability and validity of the data to be obtained. Such modifications will be coordinated among all concerned organizations in advance of any testing. Modifications of procedures or deviation from this TOP will be accounted for in the test plan and described in the test report.

(8) Figure 4 shows the recommended order in which ColPro chamber testing should be completed. Not all tests shown in this figure are required for each ColPro system; the tests performed should be based upon the requirements listed in the ColPro system's requirement documents.
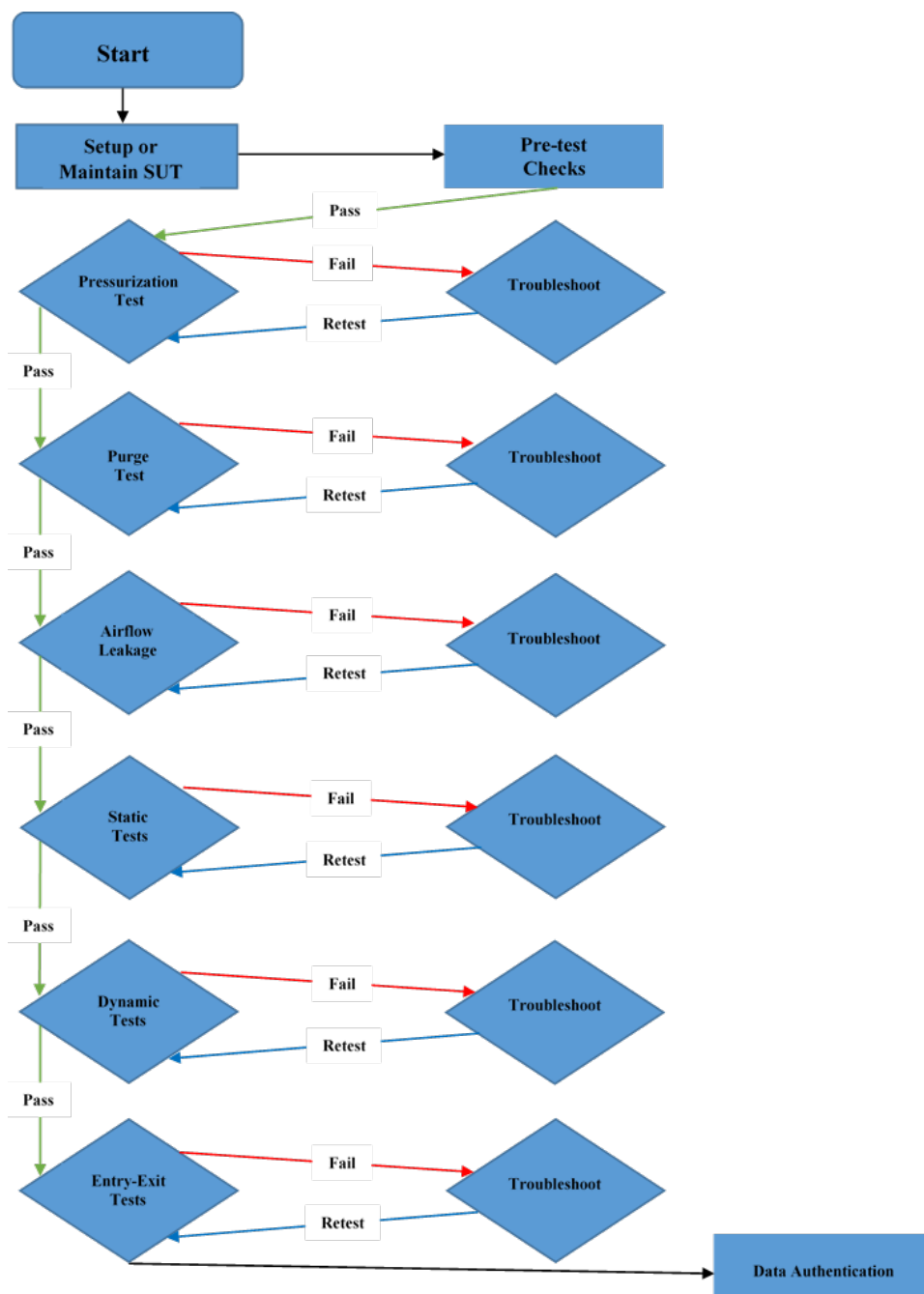
Figure 4. Recommended flow of test conduct.

3.3   Simulant Selection.

    a. Simulants are almost always employed in lieu of agents during testing and assessment of CB systems to mitigate the risks associated with the use of agents. Simulants may have chemical or physical properties that closely mimic those of agents. Simulants may have an ability to mimic the chemical or physical mechanisms of interest for agents in a given environment. Simulants may be less toxic, less expensive, and have less environmental impact than agents. In

addition, simulants do not have surety restrictions. No simulant will completely match the agent in all respects. If a system component is changed, a new simulant selection process may be required.

b. Simulants should be verified and validated before use. Selection of chemical simulants should be conducted IAW TOP 08-2-196[5]. Potential simulants will be identified and screened, simulants that best mimic the desired agents and relevant agent properties will be selected, and the selected simulants will be verified and validated. This should include verification that the simulant can be disseminated at the target concentrations, and verification that it can be analyzed in the CB laboratory at appropriate concentration levels.

c. The ability of the TFA to be cleared down after a trial to conduct multiple trials should be an important consideration in simulant validation.

d. After simulant selection is complete then an agent simulant relationship must be established IAW TOP 08-2-140[6] to validate the use of the simulant. Additional information regarding simulant selection is found in Appendix A, paragraph A.2.

3.4   Environmental Compliance.

All test site environmental requirements will be addressed before testing begins.

3.5   Test Planning.

a. Test preparations include training of test personnel in SUT function and setup.

b. Receipt inspection of the SUT and any SUT components will be performed before the start of testing.

c. Before issuance of ColPro SUTs to the TPs, ColPro SUTs should be assigned unique Test Item Control Numbers (TICNs). The TICNs can be generated during test preparation as sequential alphanumeric codes that identify the specific ColPro SUTs, or the manufacturer's serial numbers may be used.

d. Data obtained from Computational Fluid Dynamics (CFD) modeling and atmospheric dispersion modeling may be used to determine the optimal location and placement of the SUT and the instrumentation used in testing. If CFD modeling is not used, the minimum standard sampling locations inside the TFA should be at the center of the TFA, at the back corner farthest away from the filtered air inlet, and in the airlock.

e. Variations in ColPro SUT operating configurations and modes with regard to Heating, Ventilation, and Air-Conditioning (HVAC) may affect the system's protective capability. Consequently, the number of such variations determines the number of challenges to be conducted on the SUT. Each configuration or mode that may affect protective capability must be tested. Test planning should also address the adjustments and installation procedures carried out by the user that affect critical seals, and consequently, the protective capability. Among the configurations, modes, and user adjustments to be considered in test planning are those relative to: 1) air conditioners, environmental-control units, or combustion heaters with external ducts, and 2) the operating modes of integrated HVAC systems.

f. The requirements document for a ColPro system define the challenge dosage to be applied in a static challenge test of the system. If the challenge dosage is not specified by the requirements documents, a 20,000 mg-min/m^3 dosage is recommended for the chemical vapor challenge if the system's filter unit is designed for this capacity/dosage or greater. The 20,000 mg-min/m^3 value is based on threat estimates for a single, severe attack.

g. The volatility of the selected simulant and the practical limitations of generating and sustaining a concentration in a chamber determine the challenge concentration and duration of the applied challenge. The test duration is then defined as the time needed to achieve the required dosage at that concentration. A challenge concentration of 200 mg/m^3 applied for a duration of 100 minutes yields a dosage of 20,000 mg-min/m^3.

h. Test planning considerations for specific testing procedures can be found in Appendix A, paragraph A.3.

i. The importance of technical quality, completeness of test data, and conformance with specified test and operating procedures cannot be overemphasized.

3.6   Safety.

a. All test operators must read, understand, and have available the SDS associated with each chemical used in the test and with each material in the SUT. The operator is expected to be familiar with the operation of the SUT and to have read and understood the test plan. The test plan will be available to the operators at the test site.

b. If testing requires the handling and use of CB agents, then such testing is strictly controlled by U.S. Army Regulations [e.g., AR 385-10[7], Department of the Army (DA) Pamphlet (PAM) 385-61[8], and DA PAM 385-69[9]]. Throughout testing, primary emphasis must be on operator and equipment safety.

c. The required SDSs, testing protocols, and safety procedures will be available at the test site.

d. When appropriate, the test personnel will wear required Personal Protective Equipment (PPE). PPE must be approved by the Office of the Director of Army Safety (Fort Belvoir, Virginia) or meet certification standards from Occupational Safety and Health Administration (Washington D.C.) and National Institute for Occupational Safety and Health (Atlanta, Georgia) Chemical, Biological, Radiological and Nuclear (CBRN) certification standards.

e. Medical examinations or human use committee review of TPs may be required to determine physical ability to perform specified tasks. Medical examinations will be conducted before the test begins. If applicable, a medical record will be maintained on each participant.

f. Test personnel will be informed of potential safety and health hazards involved in test conduct and the precautions required to prevent accidents. A safety survey will be conducted before test execution. Other health risks may include slips, trips, falls, and exposure to hot or cold surfaces or liquids.

g. Daily safety checks and briefings will be conducted to ensure that all identified safety hazards have been addressed before testing proceeds.

h. For tests that involve carrying or lifting, test personnel and participants will be instructed in the proper lifting procedures.

i. Vehicles will be driven IAW approved test center procedures. A ColPro vehicle will be operated IAW its Operator Manual (OM).

j. If the ColPro SUT requires overpressurization, care should be taken to not overpressurize it beyond the intended operational pressure level. Overpressurization of soft-walled shelters has been known to cause rupture and irreparable damage to seams and other areas of the shelter. Overpressurization of building structures can also cause damage. TFA pressure levels for soft-walled ColPro systems should not exceed 0.8 iwg.

k. Contaminant sprayers should not be left in a pressurized state when not in use.

l. Test personnel shall be trained on the test items, test scenarios, and test conditions to include demonstration of the test item operation, and training for operation of the SUT.

3.7   Quality Assurance (QA) and Quality Control (QC).

a. All variables must be identified in the DTP. Variables that cannot be controlled shall be identified. Variables that can be controlled must have a plan with the mechanisms identified for control. Test parameters include, but are not limited to: purity of each contaminant, calibration and maintenance of instrumentation and disseminators, accuracy and precision of the laboratory instruments, accuracy of measured air flow rates for all samples collected during the testing, and quality and uniformity of all test samples.

b. The quality of instrument data is assured with appropriate instrument maintenance, periodic calibration, periodic QC checks, and careful documentation of procedures. Calibration will be conducted IAW the validated calibration protocol of the test facility. Instruments used in the testing should be calibrated as recommended by the manufacturer or according to the specific program calibration requirements. Calibration records will be maintained for all measuring and test equipment used to collect data. Calibration will be traceable to the National Institute of Standards and Technology if at all possible.

c. Data peer review, sample collection Chain of Custody (COC), and tracking and assessment of analytical results are examples of QC measures that should be identified in the DTP or QA plan.

d. Pilot trials will be performed to ensure that all test instrumentation and data collection systems are operating properly. A data authentication group should review the pilot trial data for use as record data.

e. Critical test instrumentation (e.g., the NRT monitor MINICAMS®) function checks will be performed daily to verify that the instrumentation used is operating correctly. Pre-test checks will be performed at levels that the instruments are reasonably expected to measure during the testing.

f. The use of chamber control limits are encouraged as a QC measure. Chamber control limits are derived from the permissible measurement uncertainty and the tolerance values established during chamber V&V. If the tolerance is greater than the measurement uncertainty, control limits can be set using Equations B-1 and B-2. An example of a control chart is found in Figure C-1.

g. Other QA/QC procedures specified in the DTP should be followed to ensure the highest quality of test integrity. It is recommended to analyze the data collected in these tests for accuracy using the Data Quality Objectives (DQO) outlined in the ColPro system test methodology document for SVCT[10], Dynamic Wind-Driven Challenge[11], and Entry/Exit[12] testing.

3.8   Provisioning.

a. Procure all necessary test materials for test execution.

b. Prepare COC documentation for SUTs and samplers.

c. Perform calibrations on all critical test instrumentation, obtain all calibration information for instruments, and certificates of analysis for chemicals used in testing.

d. Receipt inspection shall be performed IAW TOP 08-2-500A[13], Receipt Inspection of CB Materiel.

3.9   Air Sampling Equipment Planning.

3.9.1 Air Sampling Equipment Selection.

a. Air sampling equipment is categorized according to its analysis time, which generally varies inversely with its sensitivity. A longer sampling/analysis time yields a lower detection limit.

b. Real-time monitors provide concentration measurements immediately.

c. Near-real time samplers present concentration readings with short delays of approximately 5 to 15 minutes.

d. Delayed-analysis samplers require laboratory analysis.

e. Measurements of simulant vapor concentration in all tests are made with three types of air-sampling equipment.

(1) Real-time monitors provide concentration measurements.

(2) Near-real time samplers present concentrations with short delays of approximately 5 minutes.

(3) Delayed-analysis samplers require post-trial laboratory analysis to present concentrations.

f. TFA dosages or sequential samples are measured with delayed-analysis samplers, which also yield average concentrations for the sample period. Samplers appropriate for TFA dosages are SST, glass-bubbler impingers, and bag samplers. SSTs analyzed by Gas Chromatograph (GC) Mass Spectrometer (MS) are preferred.

g. TFA concentrations are measured with near-real-time sampling (automated GC or GCMS preferred). These provide average concentrations over a short period.

h. Challenge exposure concentrations are measured in real-time (infrared absorption spectrophotometer preferred), near-real-time (with dilution equipment), or delayed-analysis (short duration, sequenced samples).

i. Instrumentation Detection-Limit (IDL) requirements for these types of chemical vapor samplers are listed below. The accuracy requirement of ±15 percent of reading is based on the capabilities as stated by the manufacturers of these instruments.

(1) Real-time (vapor): 0.1 mg/m^3 with a dynamic range of 0.1 to 1,000 mg/m^3.

(2) Near-real-time (vapor): 0.001 mg/m^3 with a dynamic range of 0.001 to 1 mg/m^3.

(3) Delayed-analysis (vapor): 0.001 mg/m^3 for a 10-minute sample or 0.0001 mg/m^3 for a 100-minute sample. This is based on a 10 nanogram detection limit and 1 liter/minute sample flow rate.

(4) Real-time (aerosol): 0.001 µg/L with a dynamic range 0.001 to 100 µg/L. Particle counters (that are used mainly to determine the Particle Size Distribution [PSD]) normally provide particle counts per unit of sampled air. The real-time particle concentration monitors used in this testing provide concentration in terms of a mass concentration (µg/L).

(5) Delayed-analysis (aerosol): 0.001 µg/L for a 10-minute sample or 0.0001 µg/L for a 100-minute sample. This is based on a 10 nanogram detection limit and 10 liter/minute sample flow rate.

j. Method detection limits and Practical Quantitation Limits (PQL) are generally 5 to 10 times higher than the IDLs and are the values on which the protection factor calculations are based. The PQL is the lowest level that can be reliably detected with specified precision and accuracy in routine laboratory conditions. For these instruments, particularly the near-real-time and delayed sampling, the PQL is selected as the lowest non-zero standard in the calibration curve. The calibration curve is developed by graphing the known quantity of the analyte and comparing it to the instrument response, typically at five points ranging from a very low to a high concentration.

k. There must be a minimum of two independent air sampling points in the TFA, with near-real-time (MINICAMS®) and delayed-analysis samplers at each sampling point. The near-real-time sampler must have a continuous sampling system, or two time-coordinated samplers per point, so that sampling time is uninterrupted at each sampling location in the TFA. For dosage samplers, samples will be drawn with at least three sorbent tubes that are independent except for the vacuum source.

3.9.2 <u>Air Sampling Accuracy</u>.

    a. The following guidance is presented to ensure accurate air sampling in chamber tests.

        (1) During the challenge period, air samples of exposure concentrations should be measured continuously by real-time air samplers. If the samplers are located in a clean environment outside the chamber, air samples must be transported via non-absorbent sample lines (Teflon). Such sample lines typically have a higher flow rate and larger diameter than those used with near-real-time samplers (automated GC instruments) and are not required to be heated.

        (2) If extractive sampling systems are used, and they convey TFA air samples via tubing through the chamber space to instruments located outside the chamber, the sample lines must be continuous, without connectors in the chamber space.

        (3) Real-time samplers for measuring challenge concentration must not be located in the TFA to draw challenge samples into the TFA, as leakage from the exhaust port connections of the sampler can occur.

        (4) It is acceptable to place in the TFA near-real-time samplers that measure TFA concentrations. However, if operators are required to be in the TFA during the challenge period (i.e., in entry/exit tests), they must also be present in the TFA during the background sampling period and remain there throughout the challenge period. Operators in the TFA must also avoid use of commercial products (i.e., chewing gum/tobacco, lotions) that contain simulants, such as methyl salicylate, used in the test. Additional information for dealing with background levels in the TFA is found in Appendix A. paragraph A.6.

        (5) When near-real-time samplers are employed inside the TFA, standards used for check shot tests must be removed immediately from the TFA after use and well before the initiation of background sampling.

        (6) Heated sample lines must be used for all vapor samples extracted from the TFA with a maximum of four feet of unheated tubing in each line.

        (7) The flow rate of each extractive sample line should be measured while subjected to TFA operating pressures to ensure the sampling rate is unaffected by the system pressure.

    b. Sampling equipment used in the TFA must not have been used in the challenge chamber, to measure challenge-level concentrations, in previous tests. Sorbent tubes used in the TFA must not be interchanged with tubes used for the challenge concentration.

        (1) SSTs must be cleaned and verified as clean before air-sampling use. When sample tubes are re-used (after cleaning), a tube is considered clean if it contains less than the limit of detection or limit of quantification of the simulant.

        (2) TFA SST samplers must be located and configured to draw air directly into each tube. That is, tubing should not be used to convey air samples to the SSTs.

(3) Operate the GPFU positive pressure system continuously once the ColPro system is placed in the chamber or exposed to residual concentrations of simulant (i.e., before and between challenges), to prevent increases in background levels in the TFA. This measure is important to minimize the migration of residual simulant vapors from the chamber to the TFA, and consequently minimize background levels before and during the conduct of challenge tests. Continuous operation also applies in outdoor tests where residual concentrations are likely to exist between tests.

(4) Background (residual) concentrations in the TFA must be measured before each challenge trial. These data are used for correcting TFA samples and/or to determine if the test item has background concentrations sufficiently low to proceed with the challenge. Guidance on controlling background concentrations is presented in paragraph 4.5, and Appendix A (paragraphs A.6, and A.7).

(5) Total dose SSTs should be capped and placed in an air-tight container of glass or plastic once air sampling is completed. This container should be marked for test number and date, and a copy of the data sheet showing locations of tubes by number should be included in the container. Tubes used in the TFA should be placed in a separate container from any tubes used to measure challenge concentrations.

(6) SSTs should be analyzed immediately after completion of a challenge test and no more than 30 days after the samples are taken. If the analysis is performed more than one day after the samples are taken, they should be stored in a refrigerator (maximum temperature of 4 °C (40 °F)) until analyzed.

(7) An appropriate number of blanks (clean tubes) should be incorporated between samples during analytical procedures to avoid the possibility of carryover on the laboratory instrumentation.

3.9.3 Air Sampling Locations and Configuration.

a. Each TFA zone will have a minimum of two air-sampling points, each at a sample height of 3 to 5 feet above floor level. At each sampling point will be one near-real-time sampler inlet, and three co-located SST samplers (for sequential samples or total dosage measurements), each drawing air concurrently.

b. For multiple-zone shelters (i.e., enclosures with architectural barriers between spaces and filtered airflow between/among them via ducts, transfer grilles, or louvered doors) a minimum of two samplers will be placed in each zone.

c. As a minimum in each distinct zone, one sampling location will be in the center of the zone (i.e., center of TFA), and one at a corner or wall position most distant from the filtered air supply or a recirculation filter unit. These locations are to account for spatial variations in TFA concentration that may occur as a result of inefficient mixing. The use of a hand-held anemometer or theatrical smoke to determine air-sampling locations is recommended for TFAs having complex shapes or barriers that may cause inefficient mixing. CFD modeling is also recommended.

d. Seating in the TFA (for entry/exit testing) should be located so that test participants can sit near a sample point upon entering the TFA.

e. The flow through each dosage sample tube will be controlled and measured, either by the use of a MFC or critical orifice. If a critical orifice is used, the flow rate will be measured through each tube before the background sampling and again after the challenge period. Flow rate measurements must be made when a vacuum is applied to all total dose sample tubes collected for that sample period.

f. Instruments for near-real time TFA concentrations will be placed in a clean environment outside the chamber, with vapor air samples conveyed via heated sample lines of minimum length.

g. Chamber air samples of challenge concentrations and/or TP exposure concentrations will be measured continuously during the challenge/exposure period using real-time monitors. If the real-time monitors are located in a clean environment outside the chamber, the air samples must be transported via non-absorbent sample lines (e.g., Teflon for chemical vapors; Tygon or vinyl for aerosols). Such sample lines typically have a higher flow rate and larger diameter than those used in automated GC instruments and are not required to be heated.

h. Chamber samples (challenge concentration) will be taken at a minimum of two locations near the ColPro system: one on the side of the vapor source (generator) and one on the side opposite the vapor source, near the ColPro system. For entry/exit testing, one sample must be in the vapor exposure area of TPs.

4. <u>TEST PROCEDURES</u>.

4.1 <u>General</u>.

a. Analytical methodology must be validated before test execution is scheduled to begin.

b. A leak test of the filters and ECU will be conducted before any static, dynamic, or entry/exit testing to determine if the filters and ECU prevent leaks into the TFA that would cause measurable concentrations of the contaminant to exceed the breakthrough criterion. Perform leak tests around test specific penetrations (sampling lines, power lines, etc.). Complete details on pre-test check procedures are outlined in paragraph 4.4.

c. A halide leak test of the carbon filter will be performed to determine if the filtration components are sealed and installed correctly. The halide test will be performed on active systems only. Complete details on pre-test check procedures are outlined in paragraph 4.4.

d. It is recommended that an airflow mapping test be performed before static or dynamic tests. It is typically performed once per test program to capture input data for system performance modeling. The airflow mapping test will be conducted to determine the stagnant and turbulent locations around the SUT. Instruments will be placed in both stagnant and turbulent areas. No contaminant will be disseminated.

e. All test personnel entering the ColPro system (primarily for entry/exit testing) will be required to shower no more than 12 hours before the test begins. After showering, the TPs will

also be required to avoid consumer products that contain the simulant, e.g., food, soap, or clothing. No personnel who have handled simulant or used consumer products containing the simulant will be allowed to enter the ColPro system. The TPs will be given a list of products to avoid for at least a day before the test begins.

    f. Receipt inspection may include functional performance tests to establish baseline performance parameters as outlined in the test plan. ColPro SUTs should be assigned unique TICNs. The TICNs can be generated during test preparation as sequential alphanumeric codes that identify the specific ColPro SUTs, or the manufacturer's serial numbers may be used.

4.2   System Setup.

    a. The ColPro SUT will be deployed in the correct location and orientation, and operated IAW its OM. ColPro vehicles shall be fueled, driven, parked, and operated IAW procedures in the OM. Vehicles should be operated before each trial until their normal operating temperatures are reached. Preventative maintenance, checks, and services will be performed as required by the vehicle technical manual.

    b. During chamber testing the exhaust of generators, heating, ventilating and air conditioning systems, vehicles, and air-sampling instruments must be safely ducted away from personnel, chamber walls, ColPro air intakes, instrument inlets, and the command post (preferably outside of the chamber). The ColPro system air inlet will be positioned to minimize intake of dust. For a ColPro vehicle, engine combustion air and engine coolant air may be supplied from outside the chamber. Air intakes and engine exhausts shall be unrestricted. Heat generated by the engine, exhaust, or conditioning system shall not impede testing. HVAC make-up air shall be supplied from outside the chamber.

4.3   Instrumentation Setup.

    a. All the instrumentation required to conduct the test will be set up at the locations specified in the DTP.

    b. Instrumentation cables and/or sampling lines will be inserted into the ColPro SUT via pass-through ports (Figures 5 through 7) and sealed. Pre-test checks will be conducted before any static, dynamic, or entry/exit testing according to procedures outlined in paragraph 4.4.
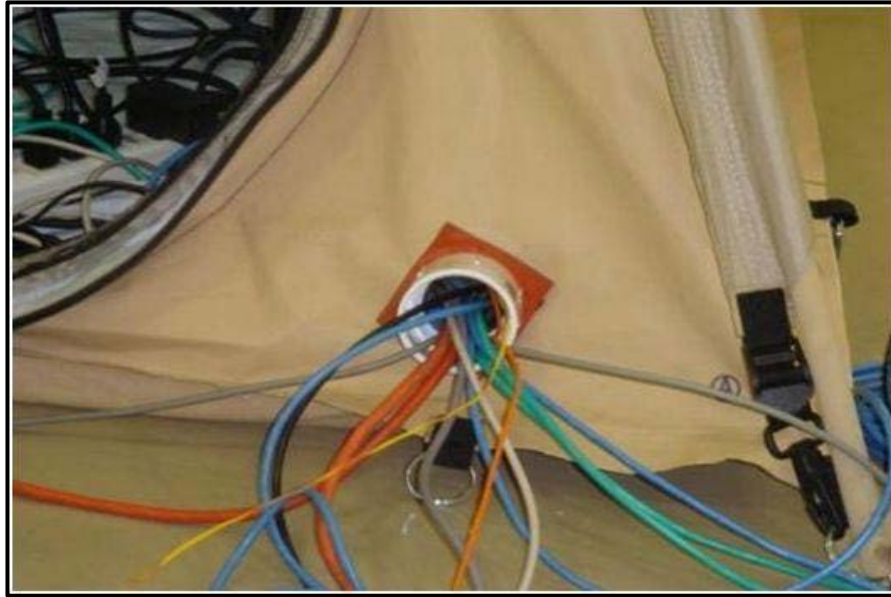
Figure 5. A ColPro system pass-through port before the port is sealed.

Figure 6. A ColPro system pass-through port packed with plumber putty to create a vapor-tight seal.

Figure 7. A fully sealed ColPro system pass-through port.

4.4 <u>Pre-Test Checks</u>.

a. Pre-test checks will be conducted when the shelter is initially configured or if degraded filter performance is suspected. Additional information is found in Appendix A, paragraph A.5.

b. The filter seal integrity will be conducted by performing vapor and particulate challenges using Polyalpha Olefin (PAO) and R-11 or R-123 halide to verify the integrity of the filters, GPFU and ECU housings, and duct connections providing overpressure to the TFA.

(1) Specifically, PAO will be used to challenge the HEPA component of the filters and identify any means of mechanical intrusion through the CB filtration, the ECU components, and through any pass-through port used to route sample tubing or data cables into the TFA.

(2) PAO will be disseminated as a particulate with an aerosol generator near the air intake of the TFA filter blower unit. Additional PAO aerosol pre-test checks will then be conducted on the ECU ducts and housing, and at the areas where the GPFU ducts are attached to the ECU (or to the TFA).

(3) Aerosol breakthrough will be monitored at the filtered air outlet into the TFA using an aerosol Real-Time Monitor (RTM) or a PAO aerosol detector system.

(4) Carbon filter integrity testing will be conducted by challenging the activated charcoal with halide. R-123 Halide will be disseminated as a vapor using a Halide generator, which is specifically designed for Halide dispersal. The target challenge for Halide is approximately 10 parts per million (ppm).

(5) Halide will be introduced directly into the air inlet of the GPFU.

(6) The concentration introduced will be monitored at the inlet and the concentration downstream will be measured at the filtered air outlet in the TFA using RTM halide detectors.

c. PAO aerosol pre-test checks will also be performed at all cable/sample line inputs to the ColPro shelter system. The PAO aerosol will be generated and directed at the cable ports and the PAO aerosol RTM will be used inside the TFA to check for any infiltration at the port area.

d. If the GPFU filter pre-test checks perform to the 99.95 percent filter capture efficiency specification, then no significant Halide or PAO (greater than 0.05 percent of the challenge concentration) will be detectable downstream. If there is a leak in the SUT, a significant amount of Halide or PAO will be detected in the TFA. The test team will attempt to identify the source of infiltration and, if feasible within the scope of the project, correct the problem. Infiltration testing will be repeated as necessary throughout testing if filters are replaced or the test team suspects degraded filter performance. Before each infiltration test, the area will be cleared of all non-essential personnel. Any personnel who remain in the area will use appropriate PPE and minimum two-man entry. Time will be allowed between test events to purge PAO or halide concentration.

4.5 Steps to be Followed if High Background Concentrations are Present.

a. Extend the purging period by operating the system for a longer period between trials. Monitor TFA concentrations continuously with NRT samplers.

b. Raise the TFA temperature while the system operates between trials to drive off simulant that has been sorbed by materials in the TFA. This is done by adjusting the SUT system thermostat to a high setting after air samples from the previous trial have been removed. The high-temperature purging is continued overnight, and the TFA temperature is returned to normal before taking background concentrations for the subsequent trial.

c. Place recirculation filter unit(s) with activated carbon in the TFA and operate continuously. The recirculation filter unit(s) must be turned off before background air sampling begins and must not operate during the test unless the filter unit is a component of the CP system being tested. TFA concentrations must come to equilibrium after the RFU is turned off before the background air sampling step (or any other portion of the test) can be started.

d. Replace the shelter liner or shelter. In chamber testing, replacing liners or shelters inside a chamber must be done in a way that prevents residual simulant in the chamber from migrating into the TFA while the CP system is being set up and is unpressurized.

e. Conduct subsequent challenges with another simulant that has been selected as described in paragraph 3.3.

4.6   Overpressure Test.

4.6.1 Method.

a. The airlock purge vents will be set to the correct position for proper operation in the standard protected mode configuration, IAW the system's OM. If systems are linked, open or close connecting doors IAW the DTP.

b. The DAS and the meteorological equipment will be started to record data at least at one-second intervals.

c. The blower will be started to begin the SUT pressurization.

d. The start time (hour, minute, second) when the filtration system blower is engaged will be recorded.

e. The SUT will be allowed to reach steady-state conditions. The steady-state pressure levels and the time to reach the minimum required pressurization levels (based on assessment criteria as defined in the DTP for pressurization tests) in the TFA and airlock of the SUT will be recorded.

f. If the pressurization level does not meet the assessment criteria, as specified by the requirement document, the procedures outlined in the OM will be followed to troubleshoot the problem. The overpressure test will be repeated.

g. If the SUT has more than one location where overpressure is measured, such as the airlock and the TFA, then the pressure monitoring instrumentation must record the pressure levels for each location.

h. After steady state pressure levels have been achieved, the power to the filtration system will be turned off. The time the power was turned off will be recorded (hour, minute, second). The time required for the TFA and airlock pressures to drop below a level specified by the DTP will be recorded.

i. The procedures in paragraph 4.6.1 will be performed on the SUT in the current configuration for a minimum of three repetitions. Other configurations must be tested with three replicate trials. The entire ColPro system (TFA and airlocks) must be allowed to completely depressurize (reach zero pressure levels) before any pressurization test is started.

4.6.2 Data Required.

a. The steady-state pressure levels attained in both the TFA and the airlock.

b. The time required to achieve the minimum required pressurization levels for the ColPro system in the TFA and airlock.

c. The time required for the steady-state condition to drop below the lower limit specified in the DTP.

4.7 Purge Test.

4.7.1 Method.

a. Purge testing demonstrates the rate the airlock of the shelter system purges contamination.

b. The ColPro system and airlock will be set up in their operational configuration, with purge vents adjusted to maintain proper pressurization levels. SUT will be turned on (the filtration system, the ECU, and purge vents opened) as required by the manufacturers instruction and DTP. All settings will be recorded, especially the purge vent settings.

c. Set up the tracer generator (vapor or aerosol) in the location outlined in the DTP.

d. For Aerosol purge testing, set up a particulate detection system RTM inside the TFA and connect to a computer DAS system to record the RTM data from the unit. For vapor purge testing, set up referee system; infra-red detectors (such as Gasmets™) can be used for CO_2 and SF_6 gases. Install sample lines from the RTM and run into the airlock at a position in the center of the airlock at a height of five feet (breathing level), or at other position as specified in the DTP. An additional sample port from the aerosol RTM should also be available to monitor TFA concentrations before testing to ensure that background concentrations in the TFA do not build up during testing. Ensure all referee systems are operating properly.

e. Initiate tracer monitoring and recording.

f. DAS data recording will be initiated. Record meteorological data throughout the trial.

g. The tracer will be released into the SUT at levels up to the higher detection limit for the referee instrument. The tracer generator is then turned off. The trial begins when the tracer drops from the high value to a level described in the DTP as the starting value. The starting concentration should be chosen at a value when the rate of concentration decay has steadied out (initial readings at the high level should not be used). The rate of decay will usually attain a steady-state rate within less than a minute. Record the start and stop times of tracer generation and the trial start time.

h. Record the time required to reduce the concentration by 1-log (90 percent reduction), 2-logs (99 percent reduction), and 3-logs (99.9 percent reduction) from the initial starting value. The trial ends when the concentration drops to an ending level as outlined in the detailed test plan. The ending level shall be at least a factor of 1000 (3-logs) lower than the starting level, but still within the measurement range of the referee instrument. Additional concentration readings below the ending level should also be recorded if still within the measurement range of the referee instrument. Record the trial end time.

i. A minimum of three repetitions will be conducted for each airlock purge trial. Complete the trial matrix for any other airlock configurations that must be conducted.

j. For shelter purge tests, install the tracer generator and referee instruments in specified locations inside the TFA (usually the center location), and test according to the same procedures outlined above.

4.7.2 <u>Data Required</u>.

     a. Tracer concentration versus time (hour, minute, second).

     b. Differential pressure.

     c. Temperature.

     d. Number of purge vents open and settings (if applicable).

     e. Tracer release start time and end time (hour, minute, second).

     f. Trial start and stop time (hour, minute, second).

4.8   <u>Static Test</u>.

These procedures apply to both vapor and aerosol testing.

4.8.1 <u>Vapor Method</u>.

     a. Ensure that all instrumentation has been calibrated properly (see paragraph 3.7).

     b. Setup ColPro SUT in the operational configuration (noted in the technical manual) in the test chamber and verify that it is operating in the correct manner.

     c. Setup all air sampling systems (see paragraph 3.9) and other test instrumentation (pressure-monitoring devices, temperature/RH monitors, etc.) in the correct locations of the SUT and the test chamber. Connect any data cables from this instrumentation to the DAS. Verify the operation of all instrumentation and connectivity/recoding of all data on the DAS.

     d. Record all of the ColPro equipment, calibration, location, and test instrumentation used in the testing.

     e. Perform pre-test checks listed in paragraph 4.4 on the GPFU, the ECU, ducting to the ECU/TFA, and all pass-through ports used in the TFA and airlock for any test instrumentation cables and tubing.

     f. Set up the chamber, vapor generation system, and the circulation fans. Ensure that the fans do not point directly at the SUT. Verify operations.

     g. Ensure that the SUT and all subsystems are operating properly. Ensure that the TFA temperatures are in specified range from the OM. If no temperature range is specified in the OM, then a standard temperature range of 21-32 °C (70-90 °F) shall be used.

     h. Perform pre-test check shots on all MINICAMS® NRT monitors to verify their performance. Inject known mass of simulant into the sample line and determine what mass is analyzed on the NRT monitor. Passing check shots are those that come within 15 percent of the injected mass.

i. Test all sampling instrumentation for proper operation, including verification that data from MFCs (if used) is transmitted to the DAS. Enter TFA using contamination avoidance procedures (outlined in Appendix A, paragraph A.7) and install SST samples (verified clean) in all TFA and airlock sample locations. The use of a MFC to collect all SST flow rate data is highly recommended. If MFCs are not used for TFA dosage samplers, the sample flow rates must be measured by inserting, in series with each sorbent tube sampler, a calibrated flow measurement device. The measurement should be performed with the same vacuum source used in the actual air sampling. For each tube, three readings should be taken before the test and three readings after the test, before removing sample tubes.

j. Verify that the DAS is collecting all of the required data.

k. TFA monitoring will begin before the initiation of the contaminant introduction into the chamber airstream. Start collection of background samples in TFA and airlock with SST samples and MINICAMS® NRT samples for the period specified in the DTP. Start all other referee instrumentation monitoring.

l. The contaminant will be introduced into an airstream which is then mixed with the chamber airstream until the target contaminant concentration at the SUT is achieved. The target concentration will be held for the time period specified in the DTP.

m. During the challenge time period, SUT subsystems may be operated in varying conditions (especially if the SUT is a vehicle).

n. At the completion of the trial, the contaminant dissemination and the TFA air sampling will be stopped.

o. Purge the test chamber of the challenge vapor or aerosol simulant concentration prior to retrieval of TFA samples. If aerosol challenge was used during this test (SPCT), all circulation fans in the test chamber will be turned off after the challenge is completed (to prevent re-aerosolization of simulant particles from the floor), and HEPA filters will be turned on in the test chamber to further reduce aerosol concentrations.

p. The TFA SSTs will be collected (ensuring strict adherence to contamination avoidance procedures specified in Appendix A, paragraph A.7), recorded on COC forms, and transported for analysis.

q. An active shelter system will continue to be operated in protective mode (with the GPFU pressurizing the shelter with cleaned air) until all challenge testing of that system has been completed.

4.8.2 Data Required.

a. Trial start and stop time.

b. All required conditions for the trial from the trial matrix in the DTP.

c. Contaminant dissemination start and stop time.

d. Time contaminant concentration remained at the desired target level.

e. All referee instrumentation results over time.

f. TFA sampling results over time.

g. TFA SST results including pre- and post-trial airflows.

h. Meteorological instrumentation results over time both inside and outside of the SUT.

i. Results of any subsystem functions.

j. Any anomalies or system failures noted during the testing.

4.8.3 Aerosol Method.

a. Referee background sampling will be conducted IAW the DTP to determine if there is a measurable residual contaminant background.

b. Aerosol dissemination nozzle systems must be setup and their operation will be verified before any testing starts.

c. Follow the procedures in paragraph 4.8.1.a through q with the exception that AGIs, PAO real time monitors, or NaFl glass fiber samples will be used instead of SST samples. APS and other particle monitors will also be used instead of Gasmets and MINICAMS® monitors.

d. Complete the trial matrix in accordance with the DTP.

4.8.4 Aerosol Data Required.

a. Trial start and stop time.

b. All required conditions for the trial from the trial matrix in the DTP.

c. Background sampling results before the challenge is started in that trial.

d. Contaminant dissemination start and stop time.

e. Time contaminant concentration remained at the desired target level.

f. All referee instrumentation results over time.

g. TFA sampling results over time measured with APS or other aerosol RTM instruments.

h. TFA aerosol sampling system results including all sample airflows for AGIs and NaFl samplers. Airflow readings using MFCs or other flow measuring devices will be conducted as specified in paragraph 4.8.1.i.

i. Meteorological instrumentation results over time both inside and outside of the SUT.

    j. Results of any subsystem functions.

    k. Any anomalies or system failures noted during the testing.

4.9   Dynamic Test.

These procedures apply to both vapor and aerosol testing. Since procedures for dynamic wind-driven challenge tests are almost the same as those used for static challenge tests (with the exception that wind is used), the procedures provided in paragraph 4.8 for Static Tests will be followed except where noted that changes are required for the wind-driven challenge testing.

4.9.1 Vapor Method.

    a. Follow all of the test procedures previously outlined for Static Tests above (paragraph 4.8) for Dynamic Tests with the exceptions outlined below for use of wind speed machines in the dynamic challenge testing.

    b. The tunnel fans will be started to develop the required trial wind speed as specified in the DTP.

    c. TFA monitoring will begin before the initiation of the contaminant introduction into the chamber airstream. Start collection of background samples in TFA and airlock with SST samples and MINICAMS® NRT samples for the period specified in the DTP. Start all other referee instrumentation monitoring.

    d. The contaminant will be introduced into an airstream which is then mixed with the tunnel airstream until the target contaminant concentration at the SUT is achieved. The target concentration will be held for a time period specified in the DTP.

    e. During the challenge time period, SUT subsystems may be operated in varying conditions (especially if the SUT is a vehicle).

    f. At the completion of the trial, the wind speed, the contaminant dissemination, and the TFA air sampling will be stopped.

    g. Complete the trial matrix.

4.9.2 Vapor Data Required.

    a. Trial start and stop time.

    b. All required conditions for the trial from the trial matrix in the DTP.

    c. Contaminant dissemination start and stop time.

    d. Time contaminant concentration remained at the desired target level.

    e. All referee instrumentation results over time.

    f. TFA sampling results over time.

g. TFA SST results including all airflow data as specified in paragraph 4.8.2.g.

h. Wind speeds and other meteorological instrumentation results over time both inside and outside of the SUT.

i. Results of any subsystem functions.

j. Any anomalies or system failures noted during the testing.

4.9.3 Aerosol Method.

a. Referee background sampling will be conducted IAW the DTP to determine if there is a measurable residual contaminant background.

b. Follow the procedures in paragraph 4.9.1.a through g (and other relevant procedure steps in paragraph 4.8) with the exception that AGIs, PAO real time monitors, or NaFl glass fiber samples will be used instead of SST samples. APS and other particle monitors will also be used instead of Gasmets and MINICAMS® monitors.

c. Complete the trial matrix.

4.9.4 Aerosol Data Required.

a. Trial start and stop time.

b. All required conditions for the trial from the trial matrix in the DTP.

c. Background sampling results before the trial challenge was started.

d. Contaminant dissemination start and stop time.

e. Amount of time contaminant concentration remained at the desired target level.

f. All referee instrumentation results over time.

g. TFA sampling results over time measured with APS or other aerosol RTM instruments.

h. TFA SST results including all sample airflows as specified in paragraph 4.8.2.g.

i. Wind speeds and any other meteorological instrumentation results over time both inside and outside of the SUT.

j. Results of any subsystem functions.

k. Any anomalies or system failures noted during the testing.

4.10 Entry/Exit Test.

a. Many of the same procedures used in the Static tests for air sampling (in the TFA, airlock, and chamber), for challenge concentration generation and monitoring, and for other data

monitoring and collection will also be used for the Entry/Exit testing. The main difference is that personnel in military clothing and IPE will be exposed to low-level concentrations of vapor (either MeS or TEP), will process through a CCA to remove IPE, and then will enter the ColPro TFA using the airlock. Liquid simulant contamination may also be applied to the IPE of TP personnel before exposure to the vapor and processing through the CCA into the shelter. In some entry/exit tests, aerosol contamination will be used instead of chemical vapor or liquid. The procedures in this section apply to both vapor and aerosol entry/exit testing.

b. All operations are timed and recorded in a time log. Entering participants/mannequins during vapor entry/exit tests remain in the challenge cloud for a period determined to be representative of that which occurs in garment removal during field entry (if IPE is not used). This exposure period is typically three minutes. They then remain in the airlock for the appropriate dwell time (including mask removal time) prior to entering the TFA. They remain in the TFA a designated period to allow for desorption of vapor. This period may be defined by the maximum capacity of the TFA or by operating doctrine and is controlled and recorded for each entry. Exits must occur so that the number of people or mannequins in the TFA at any time does not exceed the maximum occupancy of the TFA. Entries continue for the duration needed to demonstrate the required entry/exit rate.

4.10.1 Method.

a. Preparation steps for conducting entry/exit testing follow most of the same procedures in paragraph 4.8.1, but also require additional steps that include the following:

(1) Test participants must be trained in performing the entry/exit procedures properly. Pre-test runs without simulant are usually performed to ensure the TPs are adequately trained in all aspects of the procedures, including contamination exposure, CCA operations, airlock entry and purge time waiting procedures, TFA entry/waiting periods, and exit procedures for performance of multiple entries. TFA operators must avoid use of commercial products (chewing gum/tobacco, lotions, etc.) that contain simulants being used in the test.

(2) The flow rate of the GPFU filter used for pressurization of the ColPro system should be measured and recorded to ensure the pressurization flow rate is within its specified operating range.

(3) Purge-rate testing of the airlock(s) used with the ColPro shelter must be measured (using the test methodology described in paragraph 4.7) so that the proper airlock dwell time during entries will be used by the TPs.

(4) If the IPE of TPs will be contaminated with liquid simulant, an SEA will be setup for TP contamination operations. In some cases, field areas with moderate vegetation height will be sprayed with the liquid simulant and used as the SEA. Contamination density samplers must be available to place on the IPE and data collectors will be in place to remove the contamination density samplers after the TPs are contaminated.

(5) When aerosol entry/exit testing is performed, the exposure area will usually be a vegetative area separate from the test chamber where the aerosol has been applied. TPs will

walk through this area so that a more realistic manner of contamination transfer (through re-aerosolization) can occur. Artificial turf has been used in previous particulate entry/exit testing.

b. Standard preparation steps listed in paragraph 4.8.1 will then be performed in the days before testing is to be performed, including:

(1) Calibration of all instrumentation (see paragraph 3.7).

(2) Setup of ColPro SUT in the operational configuration and verification of operation.

(3) Setup of all air sampling systems (see paragraph 3.9) and other test instrumentation, verification, and connection of instrumentation data cables to the DAS. In addition to the dosage SSTs and MINICAMS® NRT monitors, sequential SSTs may also be used (if specified in the DTP).

(4) Recordation of ColPro equipment and test instrumentation used on a data sheet.

(5) Performance of pre-test checks on the GPFU, ECU, ducting, and pass-through ports listed in paragraph 4.4.

(6) Set up the chamber, vapor generation system, and circulation fans. It should be noted that nebulizer nozzle evaporation systems have been used recently to produce the lower vapor concentration levels required for entry/exit tests, and have been shown to produce much more steady concentration levels.

c. Preparation steps that will be performed on each day of the entry/exit testing include the following:

(1) Ensure that the SUT and all subsystems are operating properly.

(2) Perform check shots on all MINICAMS® NRT monitors using procedures listed in paragraph 4.8.1.h.

(3) Test all sampling instrumentation for proper operation, enter TFA and install SST samples using procedures listed in paragraph 4.8.1.i.

(4) Synchronize clocks and verify that the DAS is collecting all of the required data.

d. Since background concentrations inside the TFA can rise if the temperature rises in the TFA, the TFA temperature should be held as constant as practical during the background and challenge periods.

e. After all daily verification steps and sample setup has been completed, background air samples will be collected with SSTs (dosage and/or sequential) and MINICAMS® NRT monitors. All personnel who will be inside the TFA during conduct of the entry/exit test (including TPs, data collectors, and other test personnel) must be inside the TFA during the background collection sampling period. Personnel will enter the TFA through the airlock IAW standard entry procedures. Background samples will be collected for a minimum of 20 minutes,

or as specified in the DTP. Note: MINICAMS® NRT monitors will continue to monitor the TFA concentrations from this point through the end of the test trial.

f. Personnel will then exit the ColPro system and prepare for conduct of the entry/exit test.

g. Once the test operators have exited the TFA, monitor interior concentrations with the MINICAMS® NRT monitors until the background concentration has dropped to the acceptable level. Data collectors for the entry/exit test will be placed in the airlock and TFA at this time.

h. The vapor generation system will be started to produce the required vapor concentration inside the chamber. Gasmets (or other equivalent real time monitors) will be monitored to ensure that the concentration levels are steady.

i. For vapor exposure entry/exit testing, the following procedures will be followed for the testing. It should be noted that the test control officer will control the entry and exits of TPs in the SUT throughout all of the entry/exit testing, and the entries and exits will follow the manufacturer's specification or as described in the DTP.

(1) TPs will dress in the duty uniform and other IPE as specified in the DTP.

(2) Once the challenge has stabilized, entries begin at the rate defined by the capacity and stay time of the airlock. Data collectors outside the CP system record clock times for the start and completion of each task of entry. They also observe the procedures to ensure they are performed correctly and document any variations of the procedures.

(3) SST dosage samples will be started as soon as the first TP enters the TFA. It is preferred that this start sample time corresponds to the start of a new MINICAMS® sample cycle. Air sampling continues until one hour after the last test participant enters the TFA.

(4) Continue exposure, CCA processing, and entries to the airlock/TFA according to the schedule outlined in the DTP.

(5) Continuously monitor the challenge concentration with the RTM Gasmets, the TFA concentrations with the MINICAMS® NRT monitors, the test conditions, and sequencing of samplers.

(6) TPs will remain inside the TFA for a minimum of 60 minutes to ensure full desorption of any vapors adsorbed in the vapor exposure area after IPE has been removed. In tests where the number of TPs is limited and additional entries to the TFA are required, TPs will leave the TFA and re-perform exposures and entries to the TFA. TPs will remove their duty uniform inside the TFA, hang the garments worn inside the TFA (and leave them in the TFA for an hour), and put on a clean (unexposed) duty uniform (and any additional IPE) before leaving the TFA. Exits will be coordinated with the test control officer so that they do not interfere with entries.

(7) The test control officer coordinating the rate of entry/exit must ensure that entry processing is conducted in accordance with the procedures defined in the technical manual, field manual, or SOP for the ColPro system. Delays in entering the ColPro system from the vapor-

contaminated chamber once the protective garments have been doffed can adversely affect the results of the test.

(8) If the TFA vapor concentrations measured by the MINICAMS® NRT monitors exceed the MEG levels (above the background level), entries are halted.

(9) Entries recommence when the MINICAMS® NRT monitor readings drop to 80 percent of the MEG (above background). Data are recorded until the conclusion of the trial whether entry/exit operations are ongoing or suspended. Continue exposure and entries of TPs according to the DTP test matrix until the maximum TFA occupancy is reached, and the required entry trial duration has occurred.

(10) Continue air sampling until one hour after the last TP enters the TFA.

j. For liquid exposure entry/exit testing, the following procedures will be followed:

(1) TPs will be dressed in the trial specified IPE and contaminated with the desired contaminant.

(2) Sample slides are applied with tape to the designated locations on the ensemble for contamination density samples. As a minimum, one slide is placed on the chest, one on the upper back, and one on each of the legs, front and back. One piece of detector paper is also placed on the front and back of each subject before spraying to provide a visual indication and assist the spray operator in achieving the target density.

(3) Simulant is sprayed on each test participant from a distance of 1 to 2 meters, and the time of application is recorded. For a deposition level of 5 g/m^2 on a person's ensemble (about 2 m^2 area per person), approximately 5 g of simulant is sprayed on the front of the ensemble and 5 g on the back. This front-and-back application does not represent a realistic deposition pattern; it is used to account for all possible paths of contact transfer that may occur in the process of doffing, decontaminating, and entering.

(4) Immediately after spraying, data collectors will remove the contamination density slides from each test participant, place them in sealed containers, and transport the containers for analysis. The container is marked with the participant number and date. Density in g/m^2 is calculated by dividing the mass by the area of the slides.

(5) Entry processing begins at completion of the specified aging period, i.e., the time between application of liquid simulant and the start of entry processing.

(6) TPs proceed to the CCA and perform doffing and decontamination procedures to remove their IPE. Cross contamination will be checked by following the procedures in Test and Evaluation Capabilities Methodologies Integrated Process Team (TECMIPT) TOP IP20141201-1, Test for Cross Contamination during Doffing of PPE[14]. Then they enter the airlock and TFA following the same procedures listed in step 4.10.1.i above.

(7) TPs will be examined with point chemical detectors (if available) after entries to the TFA occur. During this period, examination of garments with a fluorescent light is performed in the TFA to identify locations on each test participant to which contact transfer has

occurred (if fluorescent tracers were added to the liquid simulant). Fluorescent light can also be used to examine the airlock interior surfaces for simulant transferred from test participants' clothing.

(8) TP contamination/entries will continue until all required entries specified by the DTP have been performed.

k. For medical ColPro system entry/exit tests, if the vapor-exposure testing is conducted with mannequins, it requires two groups of test operators to transport the mannequins into and out of the airlocks: one group in the TFA for the full duration of the test, and one group outside the ColPro system. Mannequins cannot be used in the liquid-exposure test.

(1) The TFA test operators remove the mannequins from the airlock upon entry, and place them in the airlock upon exiting. This team enters the TFA before the background sampling period is initiated so that any simulant or interferences emanating from their clothing is accounted for in the background sampling.

(2) The exterior team that operates outside the TFA remove mannequins from the airlock upon exiting and place them into the airlock upon entry. This team enters the exposure chamber only during entry/exit operations; the team remains outside the chamber while not assisting entry/exit. This team is equipped with NIOSH-approved respirators and disposable coveralls.

(3) A full complement of ambulatory patients and/or litter patients is also placed in the TFA before the background sampling period.

(4) Entries for medical tests will continue until all required entries specified by the DTP have been performed.

l. In CP systems without airlocks (e.g., M1A1 tank) TFA concentration is used to determine the length of the purge period; i.e., the time occupants must remain masked after each entry.

m. At the completion of the planned number of entries and exits, the TFA SST air sampling will be stopped, the contaminant dissemination will be stopped, and the exposure chamber will be purged. All TPs leave the TFA, but data collectors remain inside.

n. If MFCs were used, the TFA data collectors will remove, cap, bag, and tag all samples for analysis. If MFCs were not used, the TFA concentrations will be monitored with the MINICAMS® NRT monitors until levels have dropped to pre-test baseline levels, and then data collectors inside the TFA will perform post-test sample flow rate checks, and remove, cap, bag, and tag all samples for analysis. Do not conduct post-test flow checks if TFA concentrations are still high.

o. After samples are removed and sealed, the data collectors will exit the TFA and transport the samples to the laboratory (ensuring strict adherence to contamination avoidance procedures specified in Appendix A, paragraph A.7), recorded on COC forms, and transported for analysis.

p. An active shelter system will continue to be operated in protective mode (with the GPFU pressurizing the shelter with cleaned air) until all challenge testing of that system has been completed.

4.10.2 <u>Data Required</u>.

a. Trial start and stop time.

b. A time log of all entry/exit events for each TP entry and exit collected both outside the ColPro system and a second log inside the TFA and airlock.

c. A complete record of all MINICAMS® NRT Monitor vapor concentration readings collected in the TFA and airlock throughout the entire test (including background levels recorded before entries started).

d. A complete record of all Gasmet RTM vapor concentration readings collected in the test chamber throughout the entire entry/exit test exposure period.

e. Time for all vapor exposures prior to entry to the SUT.

f. Time for each TP to be liquid contaminated.

g. Time required for each TP to doff PPE and be decontaminated.

h. Time required for each TP entry and exit.

i. Time each TP remained inside the TFA after entry.

j. Time when any entries to the TFA were halted because TFA concentrations were above the MEG level; time when entries resumed; and the high concentrations recorded above the MEG level.

k. All environmental and meteorological data over time.

l. A complete identification record of all TPs that participated in the entry/exit test. This record should avoid Personal Information (PI) and focus on physiological features including height, weight, clothing sizes, boot sizes, sex, age, and any other data specified by the DTP.

m. Results of any subsystem functions.

n. Any anomalies or system failures noted during the testing.

4.11 <u>Airflow Leakage Test</u>.

4.11.1 <u>Method</u>.

a. Airflow leakage testing is conducted by attaching the airflow leakage test equipment to the ColPro shelter system (set up in its normal operational configuration), and measuring the flow rate required to pressurize the system at set increments. The airflow leakage is determined

with the purge vents set at their operational configuration (to achieve standard pressure levels in the TFA and airlock).

b. Equipment Setup.

(1) The blower will be set up IAW the vendor instruction manual. When airflow leakage testing is conducted on established ColPro SUT, the blower will generally be connected to the TFA through an additional air inlet port for a filtration system. The exhaust end of the blower will be passed through the hose fittings of the TFA and sealed using procedures normally employed in sealing GPFU duct hoses to the TFA.

(2) If there is no manual, or no additional air inlet ports are available, a transition device shall be constructed to deliver the air from the blower's exhaust into the ColPro SUT. The transition device shall be designed to accommodate the flow meter used to measure the flow rate of air provided from the blower to pressurize the TFA, and the pressure gauge used to monitor the ColPro system pressure. The transition device shall be designed so that it can be properly connected to the ColPro SUT without causing additional airflow leakage. The area where the transition device is attached to the ColPro SUT should be included as an area to be tested for airflow leakage.

(3) If the blower does not include a flow meter, then a flow meter will be installed to measure the flow rate of air provided by the variable-speed blower.

(4) A differential pressure gauge will be attached to the TFA or transition device. The reference side of the pressure gauge will be checked to ensure that it is open to ambient air. The interior tap of the pressure gauge will be placed in a position that was not affected by airflow from the blower and checked to ensure that it is open to TFA air.

(5) A computer DAS (if available) will continuously record the output readings from the flow meter and pressure gauge during testing.

(6) Meteorological equipment will be installed to measure local weather conditions during testing; specifically the temperatures and relative humidity's inside the ColPro system and outside the system must be measured. Barometric pressure should also be measured.

c. Perform a baseline of the airflow and any leakage at the inlet port or transition device with the blower operating as designed. Pressurize the ColPro system to pressure levels specified in the DTP for that ColPro system. The highest test pressure will be lower than the maximum pressure specified in the OM, to avoid damage to the ColPro SUT. Seal up any leakage noted at the inlet port or transition device.

d. Record the start and stop time for each airflow leakage test, along with the configuration of the ColPro shelter system that was tested.

e. Start the blower and pressurize the ColPro shelter system to the first incremental test pressure. When the TFA pressure reaches a steady state condition, record air flow readings required to pressurize the shelter to the first incremental test pressure on the computer DAS system. Record the average of these flow rate readings on a hand-written data sheet. Record the temperature and relative humidity conditions on the hand-written data sheet during the time the

flow rate readings are measured; also record on the computer DAS systems continuously throughout the test (if available).

     f. Raise the pressure of the shelter to the next incremental test pressure. Record the flow rate required to pressurize the shelter to this level as noted in step e.

     g. Repeat these procedures to measure and record the airflow rate required to pressurize the shelter to each of the remaining incremental test pressure levels, along with the environmental conditions.

     h. Repeat these procedures a minimum of two additional times to measure the overall airflow leakage of the test item so that three sets of data points along the incremental test pressure range can be collected.

     i. If the airflow leakage of other areas of the ColPro system (i.e., airlock, GPFU system, ECU, etc.) are to be measured, these areas will be completely sealed off from the rest of the ColPro system and additional measurements of the leakage will be performed. The difference in leakage values measured (baseline ColPro system leakage minus leakage when specific area is sealed up) is the leakage of that area.

     j. Specific areas of the ColPro SUT and/or components that have been identified for airflow leakage testing must be adequately sealed using methods that definitively isolate these components or areas from the main ColPro system. Plastic sheeting, duct tape, and duct-sealing compound can successfully seal specific areas. If systems are linked and connecting doors are to be closed, the doors shall be sealed. All identified areas shall be checked to verify that they have been adequately sealed.

     k. Complete measurements of the airflow leakage of the ColPro system after each area identified for airflow leakage testing has been sealed off from the main ColPro system following the procedures outlined above in steps d. to h.

     l. Complete the trial matrix.

4.11.2 <u>Data Required</u>.

     a. Trial start and stop time.

     b. The measured airflow leakage values at each incremental test pressure.

     c. The TFA test pressures measured when airflow leakage values were recorded at each incremental pressure.

     d. All environmental and meteorological data over time.

     e. Photographs of the ColPro system, the leakage test equipment setup, and any areas sealed during the leakage testing.

     f. Results of any subsystem functions.

g. Any anomalies or system failures observed during the testing.

5.   DATA REQUIRED.

a. The data requirements for each specific subtest are identified in Section 4.

b. Any incident occurring during testing will require the generation of a test incident report (TIR). Incidents may include, but are not limited to:

(1) Completion of a set of trials.

(2) Failure of a SUT or component(s) of a SUT.

(3) Test delays related to the SUT or SUT components.

(4) Damage to the SUT or SUT components.

c. For the entry/exit test, the number of safe entries per hour (entry rate).

NOTE: The number of exits shall equal the number of entries for the whole SUT during one trial. If systems are linked and personnel enter one system and exit another system, then the number of entries still equals the number of exits for the whole SUT.

6.   PRESENTATION OF DATA.

a. Receipt Inspection Data.

(1) Results of any function checks will be presented in the test report.

(2) Results of the initial inspection of the SUT and all components will be presented in the test report.

(3) All TICNs assigned and any serial numbers or other identification numbers during receipt inspection will be tabulated and presented in the test report.

b. Statistical Analysis of Primary Performance Measures.

(1) Statistical analysis will involve examining the variability in entry rate and net TFA dosage among several trials. For the entry rate and average TFA dosage, the mean, standard deviation, and 95 percent confidence interval will be calculated and presented in the test report.

c. Results of all leak tests will be presented in the test report.

d. Results of airflow mapping tests (areas of stagnation or turbulence) and mitigation measures taken to minimize the effects of poor airflow will be presented in the test report.

APPENDIX A. BACKGROUND INFORMATION.

A.1. <u>CHAMBER DESIGN</u>.

    a. For WDCTs, the chamber must be of a size that allows adequate (minimum of one foot) free space at the front, rear, and sides of the test item to achieve uniform flow velocity. For planning, this requires approximately 50 feet between the wind machine and the front of the test item and 50 feet from the rear of the test item to the chamber wall.

    b. The interior surfaces of the chamber should have coatings or wall materials that do not absorb chemical simulants.

    c. The chamber must have window(s) or video cameras for viewing the test item and test apparatus during the test.

    d. An airlock at one entrance to the chamber is recommended. This facilitates retention of the challenge vapor/aerosol if the chamber must be entered before it is fully purged.

    e. To accommodate test items having internal-combustion engines that must operate to provide power for the ColPro system, the test chamber must have a fan-powered exhaust removal system to prevent the release of combustion gases into the chamber.

A.2. <u>SIMULANT SELECTION</u>.

The simulants selected will usually match some physical characteristic of the agent of interest that is important to the specific test conducted. For example, in static or dynamic vapor challenge tests, the volatility and vapor pressure are the most important physical properties. Simulants that have been used in the past for vapor tests have included methyl salicylate (MeS) for distilled mustard (HD); triethyl phosphate (TEP) for soman (GD), trimethyl phosphate (TMP) for sarin (GB), and tripropyl phosphate (TPP) for persistent nerve agent (VX). For particulate challenge tests (i.e., when using aerosol surrogates for biological agents), the primary physical characteristic of importance is the particle size. Biological surrogate simulants that have been used previously include *Bacillus subtilis* var. *niger* (BG) and *Bacillus thuringiensis* (BT) for *Bacillus anthracis* (Anthrax), and Bacteriophage virus male-specific coliphage (MS2) for viruses. Inert aerosol simulants that have been used recently include poly alpha olefin (PAO) for 0.3 µm particles, and sodium fluorescein (NaFl) for 1-5 µm particles. For entry/exit testing, the physical property that is most important is the adsorption and desorption rates on clothing. MeS and TEP have been used primarily because agent-to-simulant studies have shown that the adsorption/desorption rates on military clothing are very close to HD (bis-(2-chloroethyl)sulphide) and the nerve agent GD (*O*-Pinacolyl methylphosphonofluoridate), respectively. Therefore, TEP and MeS have been validated as entry/exit simulants for GD and HD (respectively), with greater than 95 percent correlation based upon vapor pressure, volatility, and adsorption/desorption rates[15] on garments. Purge testing has used both PAO aerosols and gases; including CO_2 and SF_6. The simulants listed above may be used for those tests, or any other simulant that has been determined to be appropriate for the test. Simulants and agents used in testing glove and footwear systems are shown in Table A-1.

APPENDIX A. BACKGROUND INFORMATION.

TABLE A.1. SIMULANTS AND AGENTS USED IN TESTING; CHEMICAL AGENT
RESISTANCE TESTING OF GLOVE OR FOOTWEAR SYSTEMS.

AGENT	SIMULANT(S) USED	SIMULANT CHEMICAL ABSTRACTS SERVICE NUMBER
HD (bis-(2-chloroethyl)sulphide)	Methyl Salicylate (MeS)	119-36-8
GD (*O*-Pinacolyl methylphosphonofluoridate)	Triethyl Phosphate (TEP)	78-40-0
GB (2-(Fluoro-methylphosphoryl)oxypropane)	Trimethyl Phosphate (TMP)	512-56-1
VX (Ethyl ({2-[bis(propan-2-yl)amino]ethyl}sulfanyl)(methyl)phosphinate)	Tripropyl phosphate (TPP)	513-08-6
Bacillus anthracis (Anthrax)	*Bacillus subtilis* var. *niger* (BG)	NA
	Bacillus thuringiensis (BT)	NA
Viruses	Bacteriophage virus male-specific coliphage (MS2)	NA

A.3.   SPECIFIC TEST PROCEDURE PLANNING REQUIREMENTS.

a. For aerosol challenge tests, the target chamber concentration is that which provides a 1,000,000 ratio of challenge concentration to the TFA detection limit. For aerosol challenges, or where the dosage is not specified in a requirements document, the duration of the challenge can be determined by the air exchange rate of the TFA and the time needed to reach a steady-state concentration in the TFA with normal airflow and mixing in the TFA. The minimum duration is the time needed for three air exchanges (95 percent equilibrium), where the time for one air exchange is the volume of the TFA divided by the pressurization airflow rate.

b. Static challenge testing will be conducted at ambient temperature and humidity unless the ColPro system's requirements document specifies the protective performance in a specific range of temperature and humidity.

APPENDIX A. BACKGROUND INFORMATION.

c. Another consideration in determining the challenge concentration is the ratio of the challenge concentration outside of the TFA to the detection limit inside of the TFA. This PF should be greater than or equal to one million. For example, if the detection limit in the TFA is 0.0001 mg/m^3, the challenge concentration must be 100 mg/m^3 to demonstrate a PF of 1,000,000.

d. Test planning should address the effectiveness of the CBR filter installation procedure in establishing critical seals, when the filter units are TP installed or when the filters are installed without a leak test requirement from the SUT manufacturer. This can be accomplished by removing and re-installing the CBR filters according to the technical manual before the first challenge in a series of trials or a pre-test leak test performed before trial conduct.

e. The same test planning considerations listed in paragraphs A.3.b through d for static challenge testing apply to WDCTs also. The only difference is that the test method to be applied for WDCTs is determined by the type of ColPro system, its size, its wind speed requirement, the test objectives, and the available test facilities. The following are the two main types of ColPro systems that are tested with wind-driven challenges:

(1) Stationary CP Systems. Stationary systems should be tested at 25 mph wind speed or as specified by system requirements document at the orientation(s) in which wind-driven intrusion is most likely to occur (e.g., wind directed on the airlock).

(2) Mobile CP Systems. Mobile systems should be tested at a wind speed equal to the maximum operating speed plus 25 mph or as specified by system requirements document. For example, a 45-mph tactical vehicle would require a 70-mph relative wind speed. Mobile systems are tested at a single orientation, with the direction of the relative wind on the same axis as the normal direction of travel.

A.4.   Entry/Exit.

a. The entry/exit rate is a measure of effectiveness that varies with the following parameters:

(1) ColPro SUT performance parameters.

(2) Purge rate of the airlock.

(3) Stay time in the airlock.

(4) Stay time of each person in the TFA after entering.

(5) Ventilation rate and volume of the TFA.

(6) Individual protection parameters.

(7) Sorption/desorption rates of the test substance(s) on clothing and equipment, usually measured in separate testing.

APPENDIX A. BACKGROUND INFORMATION.

(8) Configuration and material type of protective clothing.

(9) Operational/environmental parameters.

(10) Entry procedures (detection, doffing, decontamination of clothing and equipment).

(11) Effectiveness of doffing/decontamination procedures in preventing transfer.

(12) Location of doffing (outdoors, airlock, enclosed CCA).

(13) Meteorological conditions (wind, temperature, RH, sunlight).

(14) Test substance(s) ambient concentration and type (vapor, liquid, or aerosol).

(15) Variability of contamination on personnel.

NOTE: The typical vapor concentration for exposure is 1 to 5 mg/m³. This is an estimate of the highest steady-state concentration likely to occur on a battlefield with an agent of intermediate volatility in the residual phase of a chemical attack, i.e., after the airborne aerosol released in a munitions burst has settled to the ground or dissipated. The liquid surface density of exposure is up to 10 g/m²; which is based on modeling estimates of liquid deposition levels on the battlefield contaminated by aerial-release munitions. The contaminant is applied in these tests by spraying directly on the outer garments.

b. Planning must define the entry/exit sequence and TFA dwell times of the test subjects. Entry sequences should be planned to produce the maximum required entry and exit rate the CP system is designed to support. It must also address maximum time in the TFA without exceeding the capacity while maintaining a first-in, first-out approach. Preparations for entry/exit testing have several objectives:

(1) Ensure TPs are trained in performing the entry/exit procedures properly.

(2) Ensure instrumentation and data-acquisition equipment are installed and operating properly. This includes verifying the calibration status of instruments used in the test.

(3) Ensure instrumentation and data-acquisition equipment, as installed, do not introduce leakage paths or pressures and flows that could reduce the measured protective performance of the CP system being tested or produce spurious results.

APPENDIX A. BACKGROUND INFORMATION.

(4) Ensure the exposure concentration can be achieved and maintained uniformly within the chamber at the prescribed limits. Using a simulant or tracer other than the simulant to be used in the challenge tests is recommended to minimize background concentrations.

A.5.   PRE-TEST CHECKS ADDITIONAL INFORMATION.

a. Tracer materials are used in leak testing. Leak testing is conducted to determine whether the system is providing protection to prevent leaks into the TFA that would cause measured concentrations of a contaminant to exceed the breakthrough criterion.

b. Tracer materials may be vapor or aerosol.

c. The most common vapor tracer material is a halide gas and is monitored with a halide RTM detector.

d. The most common aerosol tracer is PAO. PAO is monitored with an aerosol RTM. PAO aerosol will be used to test the high-efficiency particulate air filter component and the ECU of the system filters on active systems. For passive systems, the pass-through ports used for instrumenting the systems, passive filtration media (PFM), and other closures will be tested. Standard PAO aerosol generators that have been used include the model TDA-4A PAO generator (Air Techniques International [ATI], Owings Mills, Maryland); similar generators that produce equivalent PAO aerosol levels may also be used.

e. PAO aerosol detectors currently used include the ATI Aerosol Photometer 2H and 2I; however, alternative aerosol detectors capable of detecting aerosols at these concentration levels may also be used. Note that PAO aerosol is also used for pre-test checks of the HEPA filters of the GPFU, the installed HVAC ducting, and cable/tubing pass-through ports used for test instrumentation employed in the testing.

A.6.   BACKGROUND CONCENTRATIONS.

a. Background concentrations are those evolving from residual quantities of simulant. These present a particular problem when a simulant of low vapor pressure is used routinely or periodically in a test chamber and is retained through sorption on the chamber surfaces. With residual concentrations in the chamber, simulant can migrate into the TFA of the test item, causing background levels to rise and confounding measurements of TFA concentrations during subsequent tests. Residual concentrations in the TFA can also rise and fall with the temperature in the TFA, possibly masking changes in concentrations that may be caused by intrusion during the challenge period.

b. In the analysis of data, background TFA concentrations are subtracted from the TFA concentrations measured during the challenge period as a means of correcting for these residual levels. However, the preferred approach to background concentrations is to minimize them!

APPENDIX A. BACKGROUND INFORMATION.

c. Challenge trials should not be conducted when background concentrations inside the TFA are above 0.009 mg/m^3 (alternately, 1/3 the MEG value for the agent corresponding to the simulant being used).

d. The following are procedures for minimizing background concentrations and their effects:

(1) Once the CP system to be tested is placed in a chamber or in an outdoor area where simulant is repeatedly used, it should be operated continuously in the protective mode (e.g., pressurized) until the test series is completed. This measure is important to minimize the migration of residual simulant vapors into the TFA, and consequently minimize background levels before and during the conduct of the tests.

(2) Minimize and control entries into the TFA. Entries for preparing or removing data acquisition equipment should be minimized by installing sorbent tubes in the TFA for both background and challenge at the same time. No entries should be made into the TFA between background sampling and challenge.

(3) In a fixed chamber, the negative pressure filtration system should be operated continuously throughout all of the testing, especially after simulant has been released in the test chamber. In addition, the chamber's purging filter unit should be operated continuously between challenge tests.

(4) When test operators enter the TFA, they should wear a disposable coverall and remove it in the airlock of the test item while observing the full airlock purge period. They should also minimize their transit time in the chamber.

(5) When background concentrations exist, the TFA concentrations can rise if the temperature rises in the TFA. For this reason, the TFA temperature should be held as constant as practical during the background and challenge periods.

(6) If operators are required to be in the TFA during the challenge period, they must also be present in the TFA during the background sampling period and remain there throughout the challenge period.

e. Background aerosol concentrations in the TFA are likely to vary with the movement of people and the velocity of fan-driven flows within the TFA. Aerosols deposit on surfaces in the TFA and re-aerosolize with contact by people in the TFA or by airflow from interior fans. For both methods, changes in TFA aerosol concentrations may occur if people occupy the TFA before or during the test period or if mixing fans operate in the TFA. For testing with a fluorescent aerosol (i.e., NaFl), such increases are likely to be significant only after the first challenge in which fluorescent aerosol is employed. To minimize background concentrations, people should not occupy the TFA during or immediately before the challenge. Also, brush-type motors (e.g., in vacuum pumps) should not be employed in the TFA, as this type of motor emits fine particles.

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A.7.   TFA ENTRY CONTAMINATION AVOIDANCE PROCEDURES.

a. The following procedures have been designed to minimize transfer of contamination into the TFA after any simulant has been used in the test chamber. Any time when residual contamination is present in the test chamber, the TFA will only be entered while observing specific contamination avoidance procedures. The following are the contamination avoidance procedures that will be used when entering the TFA:

(1) Personnel entering the TFA will wear full IPE clothing when inside the chamber during any part of the challenge test (i.e., before the setting up of TFA samplers, and after testing when removing samplers).

(2) Personnel will not remain in the contaminated area of the chamber longer than necessary.

(3) The full airlock purge period will be observed during all entries to the TFA, with the purge timer being set immediately after entry to the airlock.

(4) The IPE clothing will be removed while waiting for the purge period to complete.

(5) The TFA will be entered only after the full purge period is completed.

A.8.   MASS BALANCE.

A balance may be used to weigh the disseminator before and after each trial. The weight lost may be compared to the total mass estimated from the challenge Ct. Mass balance should only be used as a last resort in verifying challenge concentration; it should be noted that mass balance can be misleading because of surface loss, misting, pooling, etc.

A.9.   USE OF SAMPLE LINES.

Sample lines may be used to connect an instrument outside the SUT to a sampling location inside the SUT. If sample lines are used, they shall be labeled at each end to identify the instrument in use and the location being sampled. They shall be robust enough to not be pinched shut or damaged during testing operations. It may be necessary to heat the sample line to transfer less volatile vapors.

A.10.   LIQUID DEPOSITION DENSITY.

One method for this measurement is the use of glass laboratory slides or filter papers (approximately 25 mm by 75 mm in size), taped temporarily to the over-garment of each TP before application of the challenge contaminant. Potential locations of the samplers are: chest, upper back, lower back, legs, forearms, and forehead. Each sampler is removed immediately after delivery of the contaminant and is placed in a separate container of solvent for later analysis to determine the mass on the sampler. Surface density in g/m^2 is calculated by dividing the total

APPENDIX A. BACKGROUND INFORMATION.

mass from the analysis by the total area of each sampler. Other adsorbent material may be used in lieu of filter paper. For liquid deposition, a swatch of detector paper is also placed on the front and back of each subject before delivery to provide a visual indication of the contaminant. The solvent used for sampler extraction depends on the validated analytical method of the test center.

A.11. INSTRUMENTATION LIMITS.

For each instrument that measures the amount of contaminant, the upper limit of quantification shall exceed the upper calibration limit, which shall exceed the highest value expected to be measured during testing. The lowest value to be measured during testing shall exceed the lower calibration limit, which shall exceed the lower limit of quantification. If an instrument can be calibrated over three decades, the upper calibration limit is 1000 times the lower calibration limit. Results shall be tabulated and shall lie between the lower calibration limit and the upper calibration limit: upper limit of quantification > upper calibration limit > results > lower calibration limit > lower limit of quantification.

A.12. SIMULANTS.

a. Simulants are often employed in lieu of agents during testing and assessment of CB systems to mitigate the risks associated with the use of agents. Simulants have chemical or physical properties that closely mimic those of agents. For example, the evaporation rate (vapor pressure) may be used as one parameter to match simulant to a CWA. Simulants have toxicity, odor, environmental impact, and regulatory restrictions. Simulants are compatible with the facilities, instrumentation, and test controls listed in paragraph A.2. Also, simulants do not have surety restrictions.

b. Simulants shall be verified and validated before being used in ColPro testing. If a new simulant is selected, then analytical methods for testing with that simulant shall be developed, verified, and validated before the simulant is used in test programs.

c. If dye or thickener is added to the simulant, the suitability of the dye or thickener shall be assessed before testing with respect to color, viscosity, or other relevant physical property. The dye or thickener shall be shown to be compatible with the materials of construction of the SUT as well as analytical and referee equipment and techniques to be used.

A.13. AEROSOL SELECTION AND MEASUREMENT.

a. Aerosol TICs, TIMs, dusty agents, and some viruses usually form a submicron aerosol. Bacterial spores and clusters of spores form particles slightly larger than 1 μm in their longest dimension. The GPFU protects the Warfighter from aerosol using HEPA filters that should be at least 99.97 percent efficient for a 0.3 μm particle.

b. For an aerosol, SUT performance may depend on the particle diameter. The particle size distribution (PSD) should be measured using a RTM. The PSD should be narrow during each trial; the full width at half maximum should be less than the mean diameter. The total

APPENDIX A. BACKGROUND INFORMATION.

concentration can be determined by integrating all the size bins of the PSD. The use of instruments that only measure concentration (mg/m³) is not recommended.

c. The best candidates for BWA simulants are materials that are similar in physical and biological properties without the pathogenicity that requires stringent handling procedures. A BWA simulant may be any material, not necessarily living, that has similar size to the agent and meets other characteristics. The simulant aerosol should have a different diameter than the background aerosol. An agent-like organism is typically a biosafety level 1 or 2 organism with physical properties similar to those of live agents but presenting a reduced level of pathogenicity, usually derived from a vaccine strain or other attenuated strain of an organism. A viral simulant may be much smaller than actual viral threat agents. An inert aerosol test is intended to provide an expedient evaluation of an approximated biological protection factor (PF) for a SUT and is not intended as a full assessment for biological aerosols. PAO or kaolin may be used to simulate submicron bioaerosol. Aqueous NaFl may be used to simulate bacterial spores. NaFl aerosol may be collected on a 47 mm glass fiber filter, rinsed off the collection medium, and then quantified by fluorescence.

A.14. <u>METHOD QUALITY OBJECTIVES (MQO)</u>.

a. MQOs shall be defined in the DTP and should drive the selection of test methods and instrumentation. MQOs ensure accurate data collection, transcription, and manipulation. Processes associated with data reporting are sample collection documentation, tracking, assessment of analytical results, and comparison of results. For example, a dissemination MQO may be expressed as shown in (Figure A.1).

b. Chamber control limits are derived from the permissible error and the tolerance established during chamber V&V. If the tolerance is less than the error of each measurement, meeting the required tolerance will not be possible. If the tolerance is greater than the error of measurement, control limits can be set using Equations B-1 and B-2 in Appendix B.

APPENDIX A. BACKGROUND INFORMATION.
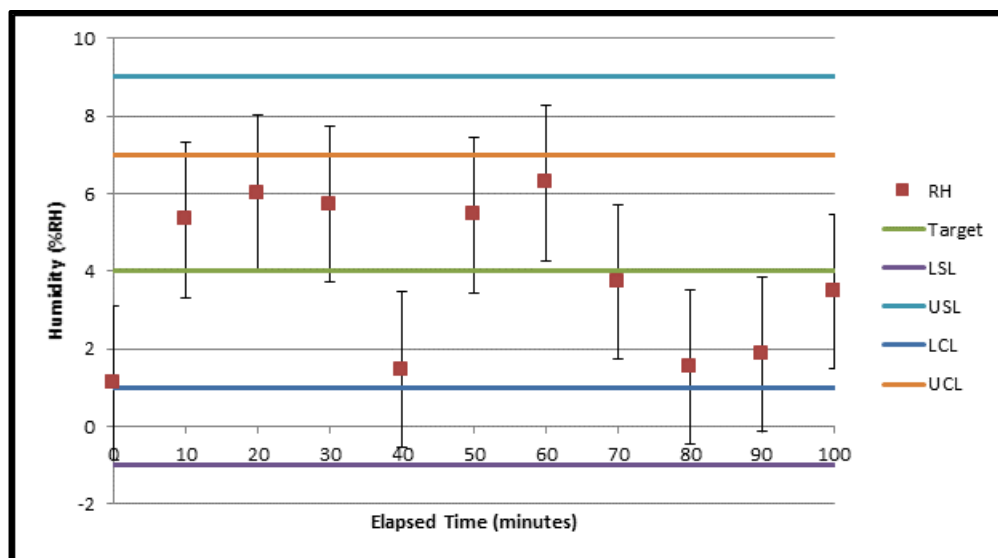
NOTE: RH – relative humidity; LSL – lower specification limit; USL – upper
specification limit; LCL – lower control limit (Equation B-1); UCL – upper
control limit (Equation B-2).

Figure A-1. Example specification and control limits based on the measurement error and
tolerance.

A.15.   ACTUAL VERSUS STANDARD CONDITIONS.

a. Actual, standard, and normal units of volume are widely used. Each test should use one
consistent set of units for volume, and specify the standard temperature used, if any.

NOTE: Depending upon the configuration of the measurement instrumentation, care shall
be taken to annotate the appropriate units of volume. Test documents shall state
explicitly which units are used to measure flow and concentration. It is
recommended to express the amount of gas in actual units, the volume occupied at
trial temperature and barometric pressure. Units of actual volume may be
prefixed with the letter a. Contaminant concentrations should also be stated in
mass per actual volume.

b. The amount of gas may also be expressed in standard units, the volume that it would
occupy at standard temperature and pressure. Because equal masses of air occupy the same
volume at standard conditions, a standard volume is effectively a mass. Standard units may be
prefixed with the letter s, such as standard liters per minute. Standard pressure is 1 atm.
Different standard temperatures are in use. If the standard temperature is 25 °C, the units are
called normal, such as normal liters per minute. If standard units are used, the standard

APPENDIX A. BACKGROUND INFORMATION.

temperature should be specified. Normal and standard volume may be converted to actual volume using Equation B-3.

A.16. <u>BACKGROUND CORRECTION</u>.

a. Air sampling in a static, dynamic, and entry/exit challenge testing is conducted in two distinct sampling periods; the background period and challenge period. During the background period, concentrations and dosages of residual simulant are measured in the TFA. Background concentrations are those evolving from residual quantities of the simulant that migrate from the test chamber to the TFA through various routes or are carried over from previous tests. These present a particular problem when a simulant having low vapor pressure is used periodically in a test chamber and is retained through sorption on the chamber surfaces.

b. Background (residual) concentrations in the TFA must be measured before each challenge trial. These data are used for correcting TFA samples and/or to determine if the test item has background concentrations sufficiently low to proceed with the challenge test. Guidance on controlling background concentrations is presented in Section A.6

c. Background concentrations are a special concern during entry/exit testing because the personnel involved as TPs may impact the background concentration levels inside the TFA. Special procedures are employed during entry/exit testing to reduce these background concentrations (having personnel shower before each trial; having personnel avoid consumer products that may have the test simulant; etc.), but background levels are still present and must be measured with all personnel inside the TFA before the start of entry/exit processing.

d. Mathematical background correction is performed by subtracting the average concentrations measured during the background period from the concentrations measured during the challenge portion of the test. When operational efforts cannot reduce the background level below the limits specified in paragraph A.6.c, the breakthrough concentration should be corrected mathematically using the most applicable option with the understanding that the uncertainty may increase dramatically. Using these corrections are a last ditch effort to save the data.

e. If pretrial readings show decay in off-gassing that is approximately exponential, then an exponential curve will be fitted to concentration data collected during the 30 to 60 minutes before trial start. The extrapolated concentrations will be subtracted from the breakthrough readings.

f. If pretrial readings are approximately constant, then the average concentration measured during the 30 to 60 minutes before trial start (or using the 20 minutes of MINICAMS® readings before trial start) will be calculated and subtracted from the breakthrough readings.

APPENDIX A. BACKGROUND INFORMATION.

g. If there are no pretrial readings and the breakthrough concentration starts to rise immediately after trial start, then the first trial reading will be subtracted from all breakthrough readings.

h. If there are no pretrial readings but the early trial readings show a clear off-gassing decay followed by breakthrough much later, then an exponential curve will be fitted to the off-gassing portion of the data. The curve will be subtracted from the readings taken during the trial period. This option will be used for data where breakthrough was not simultaneously taking place with the early off-gassing.

i. If there are no pretrial data but a clear non-zero background is present, then the first hour of the trial readings will be averaged and the average will be subtracted from the breakthrough data. This option is used for data when breakthrough does not begin until well after the first hour of the trial.

A.17.   <u>BREAKTHROUGH TIME</u>.

The breakthrough time is calculated by interpolation of the breakthrough concentration or time-weighted average (TWA) at the criterion value. Concentration criteria are of two types: threshold or TWA. Different approaches to TWA calculation have caused disagreements in test result interpretation. For the TWA, breakthrough can be defined using a trailing TWA (Equation B-4). The TWA is determined over a sliding time window ending at the time point it represents (e.g., the 1-hour TWA is the average concentration over the last hour). The time period used for the TWA shall be stated, and shall be the same as that used for the corresponding criterion. If the TWA includes a time period before data are available, then concentration will be averaged for a shorter time period (i.e., 10 minutes, 30 minutes, etc.) and either compared to other criteria (i.e., 10-minute MEG levels), or used as an estimate of the full 1-hour TWA. The Ct at the end of each trial shall be calculated using Equation B-5.

A.18.   <u>ANALYSIS AND TRANSIT TIME CORRECTIONS</u>.

The time at which a concentration is measured may be corrected to account for analysis time and transit time (time it takes for the test substance(s) to reach the instrument). Some analytical techniques, particularly for low breakthrough concentrations (e.g., preconcentration techniques), inherently have a time delay between obtaining a sample and reporting the concentration of that sample. Equation B-8 corrects the elapsed time for both transit time and analysis time. The correction for transit time is the last term in Equation B-8. The need for this correction can be reduced by minimizing the length and diameter of tubing.

A.19.   <u>ACCURACY AND PRECISION</u>.

a. Determination of Accuracy (bias) is the measure of how close to the actual value a measurement is on average. The actual value is only known if standard test items are available or if several independent measurement methods are used. The mean of several measurements with no known source of inaccuracy is used as the best (unbiased) estimate of the actual value.

APPENDIX A. BACKGROUND INFORMATION.

The metric for accuracy is the mean relative percent difference (RPD) in Equation B-9. Best practice requires at least three measurements, but seven are recommended.

b. Determination of Precision. Precision is the measure of variation in the measurement. The metric for precision is the relative standard deviation (RSD, Equations B-10 and B-11). Best practice requires at least three measurements, but seven are recommended.

A.20. UNDERTAINTY.

a. The standard reference for calculation of uncertainty is documented in the Guide to the Expression of Uncertainty in Measurement (GUM)[16]. The approach used in this procedure is considered a statistical evaluation of uncertainty by analyzing data, a Type A assessment in GUM terminology. Uncertainty is determined by combining test measurement uncertainty with an assessment of other sources of uncertainty. For many instruments, the uncertainty of the instrument is provided with the documentation.

b. Determine the test measurement uncertainty from test data using Equation B-12.

c. The uncertainty for each measurement will be determined by combining the individual uncertainties from each source, using sum of squares (Equation B-13). Sources of uncertainty include test measurement, calibration, test method, analytical solutions, sampling, test substance(s), and water vapor. Uncertainty values derived from documentation should be used when possible. The combined uncertainty is derived from the uncertainty of each applicable measurement (Equation B-13).

NOTE: The combined uncertainty may not significantly change after the highest three or four sources of uncertainty are included.

A.21. PROTECTION FACTOR (PF).

a. The PF calculation is not a required data element. In order to correlate historical data from previous trials with data from new trials, the PF of the SUT may be calculated at one location for one instrument by subtracting the background from the breakthrough Ct and dividing the challenge Ct by the net TFA Ct (Equation B-26).

b. The PF may be calculated for each instrument and at each sampler location of the exterior and interior ColPro system.

c. The individual PF values from different sampler locations may be averaged to yield the system PF.

d. PF value(s) may be compared to the PF criterion stated in the DTP. If the PF value is above this level, then the system will meet the test criterion.

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APPENDIX B. REQUIRED CALCULATIONS.

B.1.   GENERAL CALCULATIONS.

a. Control limit calculations are found in Equations B-1 and B-2.

$$LCL = V - |c| + |e|$$ *(Equation B-1)*

Where,
   LCL = lower control limit.

$$UCL = V + |c| - |e|$$ *(Equation B-2)*

Where:
   UCL = upper control limit.
   c = required tolerance allowed for each measurement.
   V = target value for the test parameter from DTPs.
   e = error of the instrumentation measuring the test parameter.

b. Normal and standard volume may be converted to actual volume using Equation B-3.

$$V_a = V_s \times \left(\frac{T + 273.15}{T_s + 273.15}\right) \times \frac{1013.25}{P}$$ *(Equation B-3)*

Where:
   V_a = the volume in actual liters.
   V_s = the standard or normal volume.
   T = the mean trial temperature in °C.
   T_s = the standard or normal temperature in °C.
   P = the mean trial barometric pressure in mbar.

$$TWA_x(t) = \frac{1}{60x} \int_{t-60x}^{t} c(t')dt''$$ *(Equation B-4)*

Where:
   TWA_x = the x hour time weighted average of breakthrough concentration in mg/m³.
   x = the length of the TWA in hours (i.e., 1 hour, 8 hours, or 24 hours).
   t'= the trial elapsed time in minutes. A different symbol is used for the limits of integration to avoid confusion with t, the elapsed time.
   $c(t)$ = concentration in mg/m³ at time t.
   t = time

APPENDIX B. REQUIRED CALCULATIONS.

$$Ct = \int_0^{t_D} c(t)dt \qquad\qquad \textit{(Equation B-5)}$$

Where:
Ct = the dosage in mg min/m³.
$c(t)$ = concentration as a function of time in mg/m³.
t = the trial elapsed time in minutes.
t_D = the trial duration in minutes.

c. The mean challenge concentration may be calculated using Equation B-6.

$$\bar{c} = \frac{Ct}{t_D} \qquad\qquad \textit{(Equation B-6)}$$

Where:
$\bar{c}$ = the mean challenge concentration in mg/m³.
Ct = the dosage in mg min/m³.
t_D = the trial duration in minutes.

d. The experimental breakthrough time can be normalized to represent the breakthrough time as if challenged at the reference (historical test results) concentration (Equation B-7). Data normalization may only be performed if the reference value is within 20 percent of the actual average challenge concentration, because breakthrough time may not necessarily be inversely proportional to concentration.

$$t' = t\frac{\bar{c_a}}{\bar{c_r}} \qquad\qquad \textit{(Equation B-7)}$$

Where:
t' = the breakthrough time normalized for challenge variation in minutes.
t = the measured breakthrough time in minutes.
$\bar{c_a}$ = the average challenge concentration measured during the test trial in mg/m³.
$\bar{c_r}$ = the reference challenge concentration in mg/m³.

APPENDIX B. REQUIRED CALCULATIONS.

$$t_c = t - t_a - \frac{t_s}{2} - \frac{V_t}{Q}$$

(Equation B-8)

Where:
t_c = the corrected elapsed time (minutes).
t = the measured elapsed time (minutes).
V_t = the actual tubing volume (liters).
Q = the flow rate in actual liters per minute.
t_a = the analysis time (minutes).
t_s = the sampling time (minutes).

e. Relative Percent Difference.

$$\overline{RPD} = \frac{100}{Nx_a} \sum_{i=1}^{N} |x_i - x_a||$$

(Equation B-9)

Where:

$\overline{RPD}$ = the mean RPD.
N = number of measurements taken during calibration.
i = the counter.
x_i = the measurements taken during calibration.
x_a = the actual value.

$$s = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2}$$

(Equation B-10)

Where:
s = standard deviation with n - 1 degrees of freedom.
n = total number of observed values.
$\bar{x}$ = mean of observed values.
i = the counter.
x_i = each measurement.

APPENDIX B. REQUIRED CALCULATIONS.

$$\text{RSD} = \frac{100s}{\bar{x}}$$

(Equation B-11)

Where:

RSD = the relative standard deviation expressed as a percentage.

s = standard deviation.

$\bar{x}$ = mean of observed values.

$$U = t_{95} \frac{RSD}{n}$$

(Equation B-12)

Where:

U = uncertainty relative to the mean.

t_{95} = Student's t distribution value for n-1 degrees of freedom at the 95 percent confidence interval.

n = number of samples analyzed (minimum of three samples, but seven is recommended).

$$U_c = \sqrt{\sum U_i^2}$$

(Equation B-13)

Where:

U_c = the combined uncertainty.

U_i = the uncertainty from each source when variables are added or subtracted. When variables are multiplied or divided, use the fractional uncertainty, i.e., U_i divided by the mean. For further discussion, see the GUM[16] or Data Reduction and Error Analysis for the Physical Sciences[17].

i = the counter.

B.2. PRESSURIZATION TEST CALCULATIONS.

The average steady-state pressure levels in the airlock and TFA will be calculated over a period of approximately 60 seconds. The average time to pressurize from zero to minimum adequate pressure levels, the average time to depressurize from steady state to minimum adequate pressure levels, and the average time to depressurize to 0.3 iwg within the TFA will be calculated. Most ColPro systems do not generally list any requirements for depressurization times; depressurization times are reported as an estimate for the time personnel would have to mask or evacuate the shelter in an emergency situation where power is lost to the GPFU. General equations specific to this test include the following equations:

APPENDIX B. REQUIRED CALCULATIONS.

$$Average\ time = \frac{Trial\ 1\ Time + Trial\ 2\ Time + \cdots + Trial\ X\ Time}{Total\ Number\ of\ Trials} \qquad \text{(Equation B-14)}$$

$$Average\ Steady\ State\ Pressure = \frac{Trial\ 1\ Pressure + Trial\ 2\ Pressure + \cdots + Trial\ X\ Pressure}{Total\ Number\ of\ Trials} \qquad \text{(Equation B-15)}$$

B.3. <u>PURGE TEST CALCULATIONS</u>.

a. The average time to purge 1-log, 2-log, and 3-log (10 percent, 1 percent, and 0.1 percent of the initial concentration) of the vapor, or aerosol particles, will be calculated. The calculations of purge rates are based on the concentration-versus-time data, which are recorded over one-second intervals during testing. These rates are calculated by plotting the concentration-versus-time data for each trial on a semi-log graph, identifying the range over which the data are linear, fitting a straight line to the linear region of the graph using least-squares regression analysis, calculating the slope and intercept of the line, and using the purge rate equation to calculate the 3-log reduction (0.1 percent of the initial concentration) times. The average 3-log reduction in concentration for each airlock in each of the various shelter configurations will be calculated. General equations specific to this test include the following.

Regression Analysis.

$$y = mx + b \qquad \text{(Equation B-16)}$$

Where:
  y = the natural log of the concentration.
  m = the rate at which the natural log of the concentration changes with respect to time (slope of line).
  x = the time in minutes.
  b = a constant (y-intercept).

b. Application of the regression equation to purge rate testing applies the concentration and time data as follows.

$$\ln (concentration) = (m) * time + constant \qquad \text{(Equation B-17)}$$

When rearranged mathematically and solved for time, the equation becomes the following.

$$time = \frac{(\ln (concentration) - constant)}{m} \qquad \text{(Equation B-18)}$$

c. After determining the equation of the line, the constants are used with Equation B-18 to calculate the time required for a given concentration reduction for each test.

APPENDIX B. REQUIRED CALCULATIONS.

B.4. <u>LEAKAGE TEST CALCULATIONS</u>.

a. The data collected represents the range of filtered air flow rate required for the ColPro shelter to be pressurized by the GPFU during normal CB protected-mode operations and the achievable shelter system pressure ranges that are achievable. The test data will be analyzed to determine the mathematical relationship between airflow and pressure. The measured airflow rates will be corrected to Normal Temperature and Pressure (NTP) conditions (20 °C and 14.696 psi) with appropriate factors based on meteorological test conditions (using Equation B-3). The achievable pressure range can be determined (using Equation B-22) by back-calculating the pressures that are obtained from the airflow leakage equations (vents closed and vents opened) when the designed airflow rate provided by the GPFU is used to pressurize the ColPro system.

b. The calculations specific to the analysis of the leakage data are included below. A log-log relationship exists between the airflow leakage data and the incremental pressure values. When the data from the leakage testing (the natural log of the airflow and pressure data values) are plotted on a linear graph, the equation coefficients of the straight line can be determined. These coefficients consist of the airflow leakage coefficient, C, and the pressure exponent, n, as defined in Equation B-19 (from American Society for Testing and Materials (ASTM) E779-03[18]).

$$Q = C(dP)^n \hspace{3cm} \textit{(Equation B-19)}$$

Where:
Q = airflow rate [m^3/s or ft^3/min (cfm)].
C = airflow leakage coefficient.
n = pressure exponent.
dP = differential pressure (Pa).

c. Rearranging this equation provides the following relationship:

$$ln\,(Q)\ =\ ln\,(C)\ + n ln(dP) \hspace{2.5cm} \textit{(Equation B-20)}$$

APPENDIX B. REQUIRED CALCULATIONS.

d. The data from all three repetitions of the leakage testing will be summarized, and the natural log of the airflow and the natural log of the pressure data values will be calculated and plotted on a linear graph. The coefficients of the straight line that is formed (where n is the slope and ln(C) is the y-intercept) will be determined algebraically using a least-squares, linear regression analysis. The constant C will be determined by taking the exponential of the ln(C) coefficient (see Equation B-21), and then these coefficients will be used in Equation B-19 to calculate the airflow leakage rate at each incremental pressure interval. If the pressure exponent n is less than 0.5 or greater than 1, then the test is invalid and must be repeated (per guidelines noted in ASTM E779-03[17]).

$$C = \exp(\ln(C))$$ *(Equation B-21)*

e. The calculated airflow readings will be converted from values of cubic feet per minute (cfm) to values corrected to actual cubic feet per minute (acfm) through the use of Equation B-3.

f. The achievable pressure range for the ColPro shelter configuration can be determined by rearranging Equation B-20 for pressures (see Equation B-22). Then the equations derived for tests with the purge vents fully closed and for tests with the purge vents fully opened will be used with these equations to determine the pressures that would be achieved when a filtered air flow rate for the GPFU used with the ColPro system is used.

$$dP = exp(\frac{[ln\,(Q)\,-ln\,(C)\,]}{n})$$ *(Equation B-22)*

B.5. <u>SVCT CALCULATIONS</u>.

a. Data of the SVCTs are analyzed in two ways:

(1) PF.

(2) TFA concentrations during challenge relative to specified MEG values.

b. PF Calculations. A protection-factor is calculated for each sampling point in the TFA based on TFA dosage and challenge dosage measured over the duration of the challenge. In sampling the TFA with sorbent tubes, dosages are calculated using the following measured values:

(1) Sample flow rate through each tube.

(2) Sampling period for each tube.

APPENDIX B. REQUIRED CALCULATIONS.

(3) Mass of simulant measured on each tube by laboratory quantitative analysis.

c. The TFA concentration calculations involve measurements made during both the background period and the challenge period. The concentration measured by each sample tube in the TFA is calculated as follows:

$$TFA\,Concentration\left(\frac{mg}{m^3}\right) = \frac{Mass(ng) \times \left(\frac{mg}{10^6\,ng}\right)}{TubeFlowRate\left(\frac{L}{\min}\right) \times Sampling\,Time(\min) \times \left(\frac{m^3}{10^3\,L}\right)} \qquad \textit{(Equation B-23)}$$

d. The average TFA concentration for each sample point is next calculated as the average of the three co-located tubes at each point.

e. TFA dosage at each sampling point is then calculated by multiplying the average TFA concentration by the sampling time, as follows:

$$TFA\,Dosage\left(\frac{mg \times min}{m^3}\right) = TFA\,concentration\left(\frac{mg}{m^3}\right) \times Sampling\,Time\,(min) \qquad \textit{(Equation B-24)}$$

f. The total challenge or exposure dosage is calculated in Equation B-25 from the average challenge concentration measured by the real-time air sampler in the chamber.

$$Total\,Challenge\,Dosage\left(\frac{mg \times min}{m^3}\right) =$$
$$Average\,Chamber\,Concentration\left(\frac{mg}{m^3}\right) \times Sampling\,Time\,(min) \qquad \textit{(Equation B-25)}$$

g. The PF is calculated in Equation B-26 for each sampling point in the TFA by subtracting the average background concentration from the average challenge-period concentration measured at each TFA sampling location and dividing the total challenge dosage by the net TFA dosage.

$$PF = \frac{Total\,challenge\,dosage}{TFA\,average\,dosage - TFA\,average\,background\,dosage} \qquad \textit{(Equation B-26)}$$

APPENDIX B. REQUIRED CALCULATIONS.

Where:
    PF = protection factor.
    The interior background dosage is calculated or estimated over the trial period.
    Dosage = mg·min/m³.

h. A PF is calculated for each sampler location. This yields a total of six values (two sample locations, three tests). The six calculated PF values are then averaged to determine the mean PF for the SUT. If more than three trials are performed, all PFs are incorporated into the average. The standard deviation and 95-percent confidence interval are also calculated.

i. If the net interior dosage is less than zero (background dosage is greater than the TFA dosage during challenge), a maximum PF value of 200,000 will be assigned to that sample location for the trial. An alternate method for calculating PF when TFA background concentrations are higher than the TFA concentrations during challenge is one that applies the method detection limit (MDL). The MDL is determined by first calculating the standard deviation of seven sample tubes; one blank and six background tubes taken during background sampling. This blank is referred to as a method blank. The MDL is calculated by multiplying the standard deviation of these samples by the one-sided t-distribution, which for seven samples (six degrees of freedom) and 99 percent confidence has a value of 3.14. The PF is then calculated by dividing the mean challenge concentration by the MDL. To illustrate this calculation, the following example uses a mean challenge concentration of 183 mg/m^3, background sample concentrations of 0.00180, 0.00166, 0.00171, 0.00174, 0.00158, and 0.00183 mg/m^3, and a blank of 0.0001 mg/m^3. The standard deviation of these seven samples is 0.00057, and the MDL is calculated as 0.00057 x 3.14 = 0.0018 mg/m^3. The PF based on the MDL is then calculated as: 183 ÷ 0.0018 = 102,000.

j. MEG Calculations. The analysis of NRT concentration data is based on discrete 5-minute or 6-minute sampling cycles, with each cycle of each sampler yielding one data point. NRT concentration data collected for each TFA sampling point will be plotted for the entire test period and analyzed according to the MEG analysis procedures.

k. The average background concentration in the TFA for the test is calculated using the last four complete cycles before initiation of the challenge (or a discreet sample period immediately before challenge is initiated). The background concentration is subtracted from each TFA concentration reading to yield background-corrected concentration values, which are used to calculate the 10-minute and the 1-hour (TWA) values. The 10-minute values are calculated from every two consecutive readings, and the 1-hour values from every 12 consecutive readings. The values are then analyzed relative to the 10-minute and 1-hour MEG criteria at each sampling point.

l. TWA concentration values must remain below the 10-minute MEG during every consecutive 10-minute period and below the 1-hour MEG during every consecutive 1-hour period of the challenge test.

APPENDIX B. REQUIRED CALCULATIONS.

m. All data points used in the calculations should be checked for outliers, or data points that do not appear to be within the expected distribution for a data set. Outliers may be rejected outright if they are caused by a known physical reason, such as a power outage, mechanical failure, or improper calibration. If there is no known physical reason, data points must be verified as outliers using statistical methods. This TOP is not intended to define specific error analysis methods for data analysis.

B.6. SPCT CALCULATIONS.

a. SPCT inert aerosol calculations. The data collected during inert aerosol particulate challenge testing of ColPro shelter systems include the challenge concentration and dosage of aerosol particulates the system was exposed to, and the concentration of any aerosols that infiltrates the TFA and/or airlock. The calculations used to determine the protective capability of ColPro systems during SPCT tests include the Safety Assurance Level (SAL; similar to PF) that the ColPro system provides to occupants inside the TFA, the percent efficiency (%EFC) for the ColPro system in preventing infiltration of biological organisms, and the background concentration of PAO and sodium Fluorescein (NaFl) particles (any inert particle of the correct size can be used) in the TFA and airlock. The procedures used to analyze the data collected during the SPCT are listed below.

b. The concentration of particles in the TFA for PAO is automatically analyzed by the PAO monitors on a mass basis (μg/L). The average concentration will be calculated during both the background period (before any challenge was disseminated) and during the challenge period. The average concentration during the challenge period will be background-corrected by subtracting out the average levels measured during the background period.

c. Concentration of Particles in the TFA for NaFl Tests. The airflow rates (preferred method for determining airflow rates is to use mass flow controllers connected to the DAS) for each sample will be averaged over the sampling time. If MFCs are used, all flow readings during the sampling period will be averaged; if MFCs are not used, the values of the flow readings for each sample will be averaged. The concentration of NaFl in the TFA will be calculated from the NaFl samples. NaFl samples will be protected from light sources during all handling and sample analysis procedures. For each NaFl sample, the filter paper will be extracted with 20 mL of recovery solution. The recovery solution consists of deionized/distilled water and 0.056 percent of Ammonium Hydroxide (approximately 1.0 N solution at a pH between 8 and 10). The total volume of the recovery solution and any rinse solution will be measured and recorded. Dilutions of the NaFl sample solution will be performed for high concentration samples. The NaFl solution analysis will be measured with a fluorometer using excitation wavelength of 490 nm and an emission wavelength of >505 nm. The liquid sample concentration will be determined from calibration curves using multiple NaFl standard concentrations that are analyzed for fluorescent excitation/emission on the fluorometer. The concentration (conc) of the NaFl air samples will then be calculated from the measured liquid

APPENDIX B. REQUIRED CALCULATIONS.

recovery solution sample concentration, the recovery solution volume, the appropriate dilution factor, the sample airflow rate, and the sample time using Equation B-27.

$$NaFl\ Conc = \frac{Liq\ conc \times dilution\ factor \times Total\ NaFL\ solution\ volume}{Average\ Flow\ Rate\ (\frac{L}{minute}) \times Sampling\ Time\ (minutes)} \quad \textit{(Equation B-27)}$$

d. The concentration for all three replicate NaFl filter paper samples collected during each sample period at each sample location will be averaged. The average background concentration will then be subtracted from the average challenge period concentration to determine the net concentration that infiltrated the TFA or airlock (see Equation B-28).

$$Net\ TFA\ Conc = Average\ challenge\ conc - Average\ background\ conc \quad \textit{(Equation B-28)}$$

e. The challenge concentration will be calculated using the concentrations calculated using Equation B-27 from all NaFl samples collected in the chamber. The average challenge concentration will then be calculated by taking the average of all chamber NaFl concentration samples (see Equation B-29).

$$\sum_{i=1}^{n}(C_i)/n \quad \textit{(Equation B-29)}$$

Where:
  Ci = the average concentration from each chamber NaFl sample.
  $i=1$ represents the first data point in the challenge period.
  n = the last data point in the challenge period.

f. The challenge dosage will be calculated by multiplying the individual chamber sample concentrations by the sampling times for each chamber sample. The total challenge dosage will then be calculated by adding up the individual challenge sample dosages (see Equation B-30). The challenge dosage can also be calculated by multiplying the average concentration of all chamber NaFl samples by the total exposure time of the ColPro system.

APPENDIX B. REQUIRED CALCULATIONS.

$$\sum_{i=1}^{n}(C_i \times \Delta t_i)$$ *(Equation B-30)*

Where:
  i=1 represents the first data point in the challenge period.
  n = the last data point in the challenge period.
  Ci = the average concentration at a given point in the challenge period.
  Δt_i = the difference in time between sampling points calculated.

g. The calculations for challenge concentration and dosage yield a mass based concentration and dosage. Theoretical calculations can be used to calculate challenge concentrations in terms of particles by using equations provided by Carlon and Guelta[19]. This reference notes that the mass concentration of an aerosol in milligrams per cubic meter is given by Equation B-31 below.

Equation B-31

$$C\ (mg/m^3) = (\pi/6) * 10^{-3} * d\ N\ D^3_{\mu m}$$ *(Equation B-31)*

Where:
  d is the density of the material (g/mL).
  N is the aerosol particle concentration per cubic centimeter.
  D_{um} is the particle diameter in micrometers.

h. When solved for N, the aerosol particle concentration (in $\mu g/cm^3$) is given by Equation B-32.

$$N = C_{(mg/m^3)} * 6/(\pi * d * D^3_{\mu m}) * 10^3$$ *(Equation B-32)*

i. Concentration of Particles in the TFA for Biological Particle Tests. The data collected during biological challenge testing of ColPro shelter SUTs includes the challenge concentration and dosage of biological spores the system was exposed to, the concentration and dosage of any biological spores that infiltrated the TFA and/or airlock, the SAL that the ColPro system provided to occupants inside the TFA, the %EFC for the ColPro system in preventing infiltration of biological organisms, and the concentration of particles in the test chamber, TFA, and airlock. The procedures used to analyze the data collected during biological SPCT are listed below.

j. Concentration of Spores in the TFA. The airflow rates for each sample will be averaged over the sampling time. The number of spores in the TFA will be derived from the AGI samples. The Petri dishes which produce the highest resolution results (from the different dilution levels) will be processed on a colony counter (or other visual counting methods). The results from all three replicate Petri dishes will be analyzed. The number of colony forming units per plate will be averaged for each AGI sample. This value, along with the appropriate dilution factor, the

APPENDIX B. REQUIRED CALCULATIONS.

total AGI solution volume, and the volume used to plate the Petri dish, will be used to calculate the average concentration of biological spores in the air in units of cfu/m^3 (or spores/m^3) for each AGI sample (see Equation B-33 or B-34).

$$Conc(\frac{cfu}{m3}) = \frac{Ns}{F*T} = \frac{Nt \times Df \times (\frac{Vagi\,(ml)}{Vp\,(\mu l)}) \times \frac{1000\,\mu l}{1\,ml}}{Flow\,Rate\,(\frac{L}{minute}) \times Sampling\,Time\,(minutes) x (\frac{m3}{1000\,L})} \qquad (Equation\ B\text{-}33)$$

Where:
  Ns = the total number of spores collected in each AGI sample.
  F = the average air flow rate (Liters/minute) through each AGI sampler during sample collection.
  T = the total sample collection time (minutes) for each AGI.
  Nt = the average number of spores counted on three Petri dishes for each AGI sample.
  Df = the dilution factor.
  Vagi = the total AGI volume (mL).
  Vp = the volume used for plating (μl) each Petri dish (100 μl used).

Or:

$$Conc(\frac{cfu}{m3}) = \frac{10,000\,Nt \times Df \times Vagi}{F \times T} \qquad (Equation\ B\text{-}34)$$

k. The concentration determined for each AGI will be averaged for all AGIs collected at each sample location during each sample period. The average concentration measured during the background period will be subtracted from the average concentration measured during the challenge period. This difference is the Net TFA (or airlock) concentration in cfu/m^3 (see Equation B-28).

l. The average challenge concentration will be calculated using the concentrations calculated with Equation B-34 from all AGI samples collected in the chamber and averaging the concentration value from all AGI samples. The total dosage that the SUT was exposed to during the biological challenge testing will be calculated by summing up the concentration-time products for all of the AGI samples collected in the test chamber (see Equation B-35). This dosage will be calculated for each chamber sample location, and then averaged from the data collected at the two sample locations. The challenge dosage is reported in units of cfu-minutes/m^3 (cfu-min/m^3).

APPENDIX B. REQUIRED CALCULATIONS.

$$\sum_{i=1}^{n}(A_i \times \Delta t_i)$$
<div align="right">*(Equation B-35)*</div>

Where:
  i=1 represents the first data point in the challenge period.
  n represent the last data point in the challenge period.
  Ai is the average concentration determined from the AGI samples at a given point in the challenge period.
  Δt_i is the difference in time between sampling points calculated using Equation B-36.

$$\Delta t_i = t_i - t_{i-1}$$
<div align="right">*(Equation B-36)*</div>

m. The biological challenge dosage can also be calculated by multiplying the average concentration of all chamber AGI samples (calculated with Equation B-34) by the total exposure time of the ColPro system using Equation B-37.

$$Challenge\ Dosage = Average\ Chamber\ Concentration \times Total\ Exposure\ Time$$ *(Equation B-37)*

n. The %EFC is a measure of how well the ColPro system prevents biological organisms from infiltrating the protected area (TFA) and/or airlock of the shelter from external challenge contamination (inert aerosol or biological). The %EFC is equal to the ratio of the average challenge concentration minus the net TFA Concentration, divided by the average challenge concentration (see Equation B-38).

$$\%EFC = \frac{(Avg\ Challenge\ concentration - Avg\ Net\ TFA\ concentration)*100\%}{Avg\ Challenge\ concentration}$$ *(Equation B-38)*

o. The SAL is based upon the ratio of aerosol concentration (inert aerosol or biological) measured inside the TFA to aerosol concentration measured outside the TFA. This value is calculated using the net TFA concentration calculated for the TFA (Equation B-28) and the average challenge concentration (Equation B-29) as shown in Equation B-39. If the net TFA concentration is zero or below background levels, a maximum value of 1,000,000 will be reported as the SAL (10^6 is the industry standard recommendation for hospital decontamination of biological organisms). Higher levels could be assigned, but there is very little difference in

APPENDIX B. REQUIRED CALCULATIONS.

values greater than 1,000,000 since very small changes in low-level net concentrations cause tremendous increases in SAL values.

$$SAL = \frac{Average\ Chamber\ Challenge\ concentration}{(Average\ TFA\ Challenge\ concentration) - (Average\ TFA\ Background\ concentration)}\ (Equation\ B\text{-}39)$$

B.7. <u>WIND-DRIVEN CHALLENGE TEST CALCULATIONS</u>.

The same calculations used for SVCT and SPCT will be used for Wind-Driven challenge testing. The average wind speed may also be calculated.

B.8. <u>ENTRY/EXIT CHALLENGE TEST DATA REDUCTION</u>.

a. The main analysis tools include calculation of the average entry rate and performing TWA analysis on the MINICAMS® concentration data collected in the TFA.

b. Entry Rate Data Reduction. The timing data recorded during each entry/exit test will be tabulated with the specific time each TP enters the TFA, how long they remain in the TFA, and when they leave the TFA so that the time between entries can be calculated. The standard entry rate to the ColPro system for each test will be calculated by dividing the number of TP entries to the TFA by the total entry time period. The total entry time period is defined as the time between when the first TP enters the TFA and the last TP enters the TFA. The standard entry rate has always been assessed as the safe entry rate (from contaminated environments) to shelter systems because the first entry to the TFA is the point where contamination (adsorbed vapors on clothing and/or liquid contamination) may be brought into the TFA. This rate can be used as long as TFA concentrations are below MEG levels. A secondary entry rate based upon the airlock usage can also be calculated. The total entry time period for the airlock entry rate calculation is defined as the time between when the first TP enters the airlock and the last TP enters the TFA. This airlock entry rate is thought to be more of a total system entry rate.

c. Entry Timing Data Reduction. During vapor Entry/Exit Tests or particulate Entry/Exit Tests, the time when each TP enters the TFA is recorded. The time between each TP entry and the previous entry is calculated and averaged to provide the average time between entries in each trial.

d. Procedures outlined in Section B.5 will be followed to calculate the 10-minute, the 60-minute, and the 8-hour estimated TWA concentration values during the entry/exit testing. The appropriate average background TFA concentration will be subtracted from each MINICAMS® concentration reading during the entry period, and the average background-corrected concentration from each time period (10 minutes, 60 minutes, or up to 8 hours) will be used to compute the calculated TWA concentration values for this testing. Background concentrations should be measured with all TPs and data collectors present inside the TFA to account for incidental background concentrations that may be present. These calculated TWA values will then be compared to the appropriate time period MEG performance criterion values for the

APPENDIX B. REQUIRED CALCULATIONS.

simulant that is used (HD agent MEG values for MeS, and nerve agent GD MEG values for TEP).

e. The timing data recorded during each entry/exit trial will be tabulated so that the specific time period when each TP was inside the TFA without a mask can be determined. The background-corrected MINICAMS® concentration data will be analyzed to determine the average concentration present in the TFA at each sample position during the TFA-stay period for each TP. The TFA exposure dosage at each sample location will be calculated from the summation of the concentration data multiplied by the sample period time (5 minutes) for each MINICAMS® reading during the time period when each TP remains inside the TFA. The dosage will then be averaged between all TFA sample positions to determine the specific dosage each TP was exposed to while unmasked inside the TFA. The TFA exposure dosages for all TPs will be averaged to determine the average TFA exposure dosage for all TPs during each entry/exit trial.

f. The timing data recorded during each entry/exit trial will be tabulated so that the specific time period when each TP was exposed to vapor simulant in the exposure area can be determined. The exposure area concentration data recorded by the Gasmet™ RTMs (see Figure C-2) will be analyzed to determine the average concentration present for each exposure period. The exposure dosage will be calculated by multiplying the average concentration present for each TP by the total exposure time they were in the exposure area. The exposure dosages for all TPs will be averaged to determine the average exposure dosage for each entry/exit trial.

g. If TFA concentration levels exceed MEG levels during entry/exit testing, all entries will be stopped until the TFA concentration decreases to 80 percent of the 60-minute MEG criteria level. Each time this occurs, the time required to reduce the concentration will be recorded. The time that entries are halted will be transposed directly from the entry/exit time log.

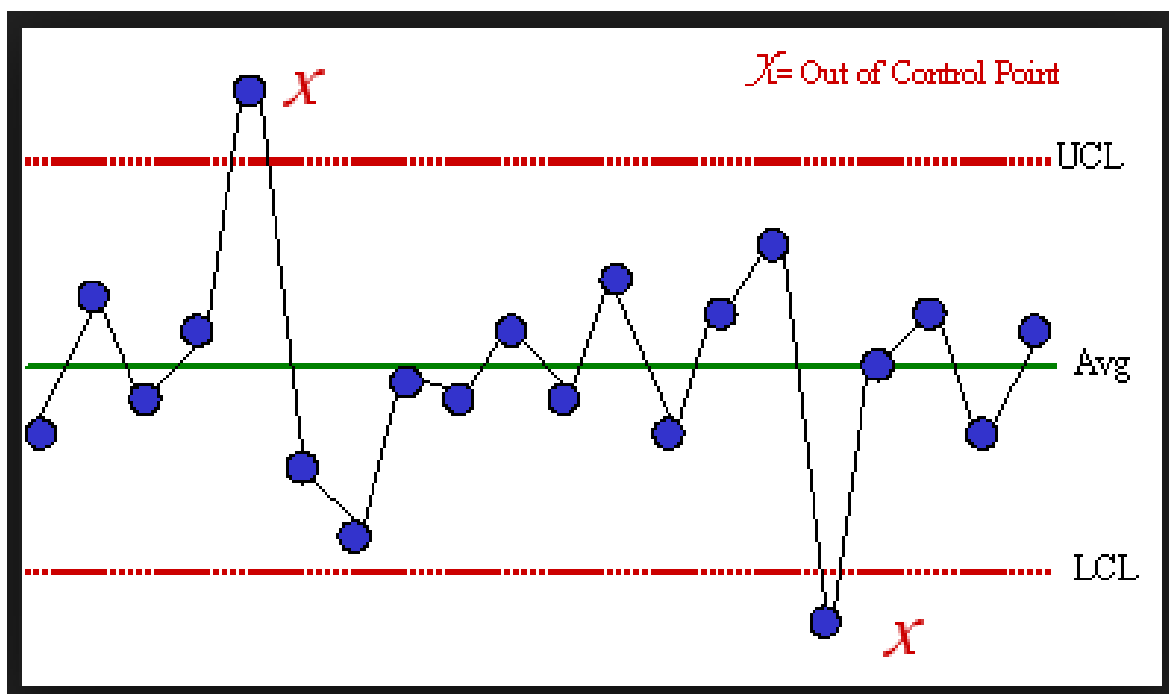APPENDIX C. EXAMPLES OF DATA PRESENTATION.

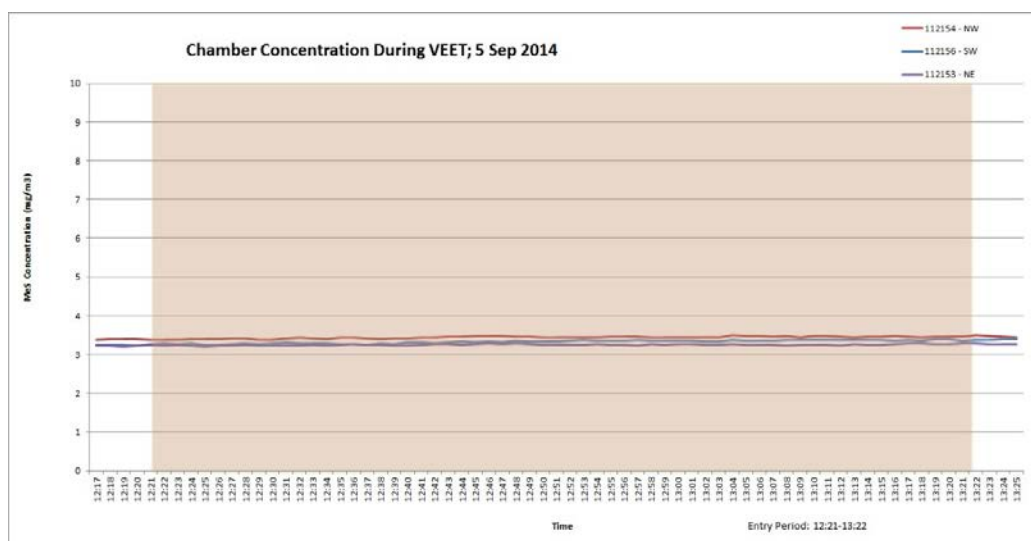

Figure C-1. Control chart example.

Figure C-2. Gasmet™ results for the methyl salicylate (MeS) challenge concentration in the
Contamination Control Area (CCA).

APPENDIX C. EXAMPLES OF DATA PRESENTATION.

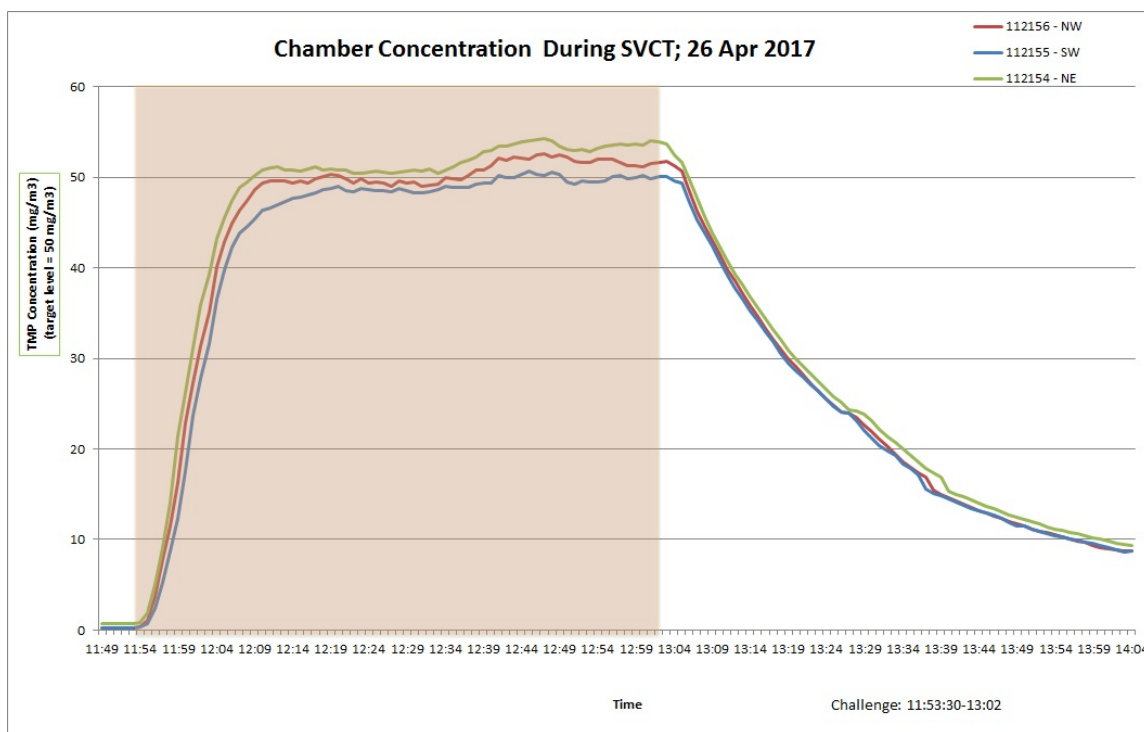Figure C-3 presents the graph of the simulant concentration over time.

Figure C-3. Simulant concentration over time.

APPENDIX D. ABBREVIATIONS.

%EFC	percent Efficiency
°C	degree Celsius
°F	degree Fahrenheit
AD No.	Accession Number
AGI	All-Glass Impinger
APC	Air Purification Component
APG	Aberdeen Proving Ground
APS™	Aerodynamic Particle Sizer
ASTM	American Society for Testing and Materials
ATEC	U.S. Army Test and Evaluation Command
ATI	Air Techniques International
BG	*Bacillus Subtilis* var. *niger*
BT	*Bacillus Thuringiensis*
BWA	Biological Warfare Agent
CAPAT	Capability Area Process Action Team
CB	Chemical and Biological
CBR	Chemical, Biological, and Radiological
CBRN	Chemical, Biological, Radiological, and Nuclear
CCA	Contamination Control Area
CFD	Computational Fluid Dynamics
CO_2	Carbon Dioxide
COC	Chain of Custody
ColPro	Collective Protection
CONOPS	Concept of Operations
CRDEC	Chemical Research, Development & Engineering Center
CWA	Chemical Warfare Agent
DA	Department of the Army
DAS	Data Acquisition System
DPG	U.S. Army Dugway Proving Ground
DQO	Data Quality Objective
DTP	Detailed Test Plan
ECBC	Edgewood Chemical Biological Center
ECU	Environmental Control Unit
FFA	Fan Filter Assembly

APPENDIX D. ABBREVIATIONS.

GB	Sarin
GC	Gas Chromatograph
GD	Soman
GE	Genome Equivalent
GPFU	Gas Particulate Filter Unit
GUM	Guide to the Expression of Uncertainty in Measurement
HD	Distilled Mustard
HEPA	High Efficiency Particulate Air
HVAC	Heating, Ventilation, and Air-Conditioning
IAW	In Accordance With
IDL	Instrumentation Detection-Limit
IEC	International Electrotechnical Commission
IPE	Individual Protective Equipment
ISO	International Organization for Standardization
LCL	Lower Control Limit
LSL	Lower Specification Limit
MDL	Method Detection Limit
MEG	Military Exposure Guideline
MeS	Methyl salicylate
MFC	Mass Flow Controller
MQO	Method Quality Objectives
MS	Mass Spectrometer
MS2	Male-Specific Coliphage
NaFl	Sodium Fluorescein
NRT	Near-Real Time
NTP	Normal Temperature and Pressure
OM	Operator Manual
PAM	Pamphlet
PAO	Poly alpha Olefin
PCR	Polymerase Chain Reaction
PE	Protective Entrance
PEET	Particulate Entry/Exit Test
PF	Protection Factor
PFM	Passive Filtration Media
PI	Personal Information

APPENDIX D. ABBREVIATIONS.

ppb	parts per billion
PPE	Personal Protective Equipment
ppm	parts per million
PQL	Practical Quantitation Limit
PSD	Particle Size Distribution
QA	Quality Assurance
QC	Quality Control
RFU	Recirculation Filter Unit
RH	Relative Humidity
RPD	Relative Percent Difference
RSD	Relative Standard Deviation
RTM	Real-Time Monitor
SAL	Safety Assurance Level
SDS	Safety Data Sheet
SEA	Simulant Exposure Area
SF_6	Sulfur Hexafluoride
SPCT	Static Particulate Challenge Test
SST	Solid Sorbent Tube
SUT	System Under Test
SVCT	Static Vapor Challenge Test
TECMIPT	Test and Evaluation Capabilities Methodologies Integrated Process Team
TEP	Triethyl Phosphate
TFA	Toxic-Free Area
TIC	Toxic Industrial Chemical
TICN	Test Item Control Number
TMP	Trimethyl Phosphate
TOP	Test Operations Procedure
TP	Test Participant
TPP	Tripropyl Phosphate
TTOP	TECMIPT TOP
TWA	Time-Weighted Average
UCL	Upper Control Limit
U.S.	United States
USL	Upper Specification Limit

APPENDIX D. ABBREVIATIONS.

V&V	Verification and Validation
VEET	Vapor Entry/Exit Test
VX	Persistent Nerve Agent
WDCT	Wind Driven Challenge Test

APPENDIX E. REFERENCES.

1. TOP 08-2-504, Near Real Time Swatch Testing, DRAFT, TBD.

2. TOP 08-2-197, Chemical Protection Testing of Sorbent-Based Air Purification Components (APCs), 24 June 2016.

3. TOP 08-2-201, Collective Protection (ColPro) Novel Closures Testing, 28 March 2013.

4. TOP 08-2-198, Collective Protection (ColPro) Field Testing, 28 September 2011.

5. TOP 08-2-196, Simulant Selection for Laboratory, Chamber, and Field Testing 25 April 2011.

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11. US Army Research, Development and Engineering Command, Edgewood Chemical Biological Center (ECBC), Aberdeen Proving Ground, Maryland, ECBC-TR-849, Test Standard for Wind-Driven Challenge Testing of Pressurized Collective Protection Systems, April 2011.

12. US Army Research, Development and Engineering Command, Edgewood Chemical Biological Center (ECBC), Aberdeen Proving Ground, Maryland, ECBC-TR-873 Test Standard for Entry/Exit Testing and Purge Rate Measurements for Collective Protection Systems, June 2011.

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APPENDIX E. REFERENCES.

16. International Organization for Standardization (ISO), Geneva, Switzerland, ISO/International Electrotechnical Commission (IEC) Guide 98-3:2008, Guide to the Expression of Uncertainty in Measurement (GUM), first edition 2008, revised 2010.

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19. Chemical Research, Development & Engineering Center (CRDEC), Aberdeen Proving Ground (APG), Maryland, Safe Replacement Materials For DOP In "Hot Smoke" Aerosol Penetrometer Machines, CRDEC-TR-333, March 1992.

APPENDIX F. APPROVAL AUTHORITY.

CSTE-CI   4 September 2019

MEMORANDUM FOR

Commanders, All Test Centers
Technical Directors, All Test Centers
Directors, U.S. Army Evaluation Center
Commander, U.S. Army Operational Test Command

SUBJECT: Test Operations Procedure 08-2-199 Collective Protection System
Chamber Tests, Approved for Publication

1. Test Operations Procedure (TOP) 08-2-199 Collective Protection (ColPro) System
Chamber Tests, has been reviewed by the U.S. Army Test and Evaluation Command
(ATEC) Test Centers, the U.S. Army Operational Test Command, and the U.S. Army
Evaluation Center. All comments received during the formal coordination period have
been adjudicated by the preparing agency. The scope of the document is as follows:

    This TOP provides basic information to facilitate planning, conducting, and reporting
testing of ColPro active and passive systems in a chamber. Systems include active
shelters, passive shelters, and vehicles. This TOP provides a set of tests to assess the
air handling, chemical/biological protective capability, and operational performance of
ColPro systems. Pressurization, airflow, purge, leakage, static challenge, dynamic
wind-driven challenge, and entry-exit tests are included in this TOP. The contaminant
may be a toxic industrial chemical vapor, simulant vapor, or aerosol of agent-like
organism.

2. This document is approved for publication and will be posted to the Reference
Library of the ATEC Vision Digital Library System (VDLS). The VDLS website can be
accessed at https://vdls.atc.army.mil/.

3. Comments, suggestions, or questions on this document should be addressed to U.S.
Army Test and Evaluation Command (CSTE-TM), 6617 Aberdeen Boulevard-Third Floor,
Aberdeen Proving Ground, MD 21005-5001; or e-mailed to usarmy.apg.atec.mbx.atec-
standards@mail.mil.

ZWIEBEL.MICHA Digitally signed by
EL.J.1229197289 ZWIEBEL.MICHAEL.J.1229197289
Date: 2019.09.10 08:51:25 -04'00'

MICHAEL J. ZWIEBEL
Director, Directorate for Capabilities
    Integration (DCI)

APPENDIX F. APPROVAL AUTHORITY.

TECMIPT Test Operations Procedure (TTOP) 08-2-199 Collective Protection (ColPro) System Chamber Testing

Protection Capability Area Process Action Team (CAPAT):

West Desert Test Center, US Army Dugway Proving Ground (DPG)

CAPAT Review & Concurrence: December 2018

Test and Evaluation Capabilities and Methodologies Integrated Process Team (TECMIPT) Participants:

REFERENCES:
(a) *Chemical and Biological Defense Program (CBDP) Test and Evaluation (T&E) Standards Development Plan*, dated 19 July 2010.
(b) *Memorandum of Understanding (MOU) Among the Department of National Defence of Canada the Secretary of State for Defense of the United Kingdom of Great Britain and Northern Ireland and the Secretary of Defense on Behalf of the Department of Defense of the United State of America concerning the Research, Development and Acquisition of Chemical, Biological and Radiological Defense Materiel*, dated June 2000. Amendment One, dated August 2006.

APPENDIX F. APPROVAL AUTHORITY.

TECMIPT Test Operations Procedure (TTOP)
08-2-199 Collective Protection (ColPro) System Chamber Testing Concurrence Sheet

The Protection CAPAT recommends approval of TTOP 08-2-199. If a representative non-concurs, a dissenting position paper will be attached.

Organization	Signature	Date
Deputy Under Secretary of the Army Test and Evaluation (DUSA-TE)	OBRIEN.SEAN.P.1230553501 Digitally signed by OBRIEN.SEAN.P.1230553501 Date: 2018.11.26 11:53:42 -05'00' Sean P. O'Brien	_____
Joint Program Executive Office of Chemical Biological Defense (JPEO-CBRND) Test & Evaluation	Joseph Rybak	6/17/2019
Joint Requirements Office for Chemical, Biological, Radiological and Nuclear Defense (JRO-CBRND)	LTC Paul M. McManus, USA	03APR19
Joint Science and Technology Office (JSTO)	Thomas R y Tom Yuzuik	6-24-19
US Army Evaluation Command (AEC)	YOST.EMILY.D.1245776124 Digitally signed by YOST.EMILY.D.1245776124 Date: 2019.04.23 10:49:30 -04'00' Emily Yost	_____
Operational Test and Evaluation Force (OPTEVFOR)	R Ramirez CAPT R Ramirez, USN	_____
Air Force Operational Test and Evaluation Center (AFOTEC)	Phillip E. Hoyt, Maj, USAF	17 Apr 19
Marine Corps Operational Test & Evaluation Activity (MCOTEA)	WADLEY.MICHAEL.CRAIG.1130810841 Digitally signed by WADLEY.MICHAEL.CRAIG.1130810841 Date: 2019.03.25 07:51:29 -04'00' Michael Wadley	_____
Naval Surface Warfare Center Dahlgren Division (NSWC-DD)	POMPEII.MICHAEL.A.1229019224 Digitally signed by POMPEII.MICHAEL.A.1229019224 Date: 2019.04.29 10:08:57 -04'00' Mike Pompeii	_____
Edgewood Chemical Biological Center	Roderick A. Fry Roderick A. Fry	29 Nov 2018
Warfighter Protection CAPAT Co-Chair	FITHIAN.ROBERT.C.1401863199 Digitally signed by FITHIAN.ROBERT.C.1401863199 Date: 2019.03.28 15:31:24 -04'00' Robert Fithian	_____
	Dr. Brian Dressen	6-25-19

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Forward comments, recommended changes, or any pertinent data which may be of use in improving this publication to the following address: Policy and Standardization Division (CSTE-CI-P), U.S. Army Test and Evaluation Command, 6617 Aberdeen Boulevard, Aberdeen Proving Ground, Maryland 21005-5001. Technical information may be obtained from the preparing activity: Commander, US Army Dugway Proving Ground (TEDT-DPW-TT), Dugway, Utah 84022-5000. Additional copies can be requested through the following website: https://www.atec.army.mil/publications/documents.html, or through the Defense Technical Information Center, 8725 John J. Kingman Rd., STE 0944, Fort Belvoir, VA 22060-6218. This document is identified by the accession number (AD No.) printed on the first page.